A GROUP OF MODELS AND PROJECTS FOR USE

IN THE STUDY OF PHYSICS

by

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INTRODUCTION

The scientific method and its laboratory were introduced to the world by Galileo. As was shown by his invention of a telescope for mariners, Galileo pioneered the practical applications of physics, as well as being the father of its pure science. Much progress has been made since the days of Galileo. Literally thousands of discoveries have been made by as many scientists. The modern high school laboratories excel the laboratories of the universities of a few decades ago. However, the benefits have not been unmixed with defects. Some of the latter now present themselves as serious educational problems. One of these is the individual's lack of sufficient interest to secure an understanding of a problem. Exercises are done mechanically to proceed to the next step in the educational system, or merely to get a credit toward graduation. There is a need for an understanding and appreciation of science for the sake of science in the same way that the musician expresses himself in music for the joy of the performance. An appreciation of this nature early in life will be the ideal foundation upon which the scientific leadership of tomorrow must be built.

A second problem originates in the complexity of the modern world. The pre-school child can talk in terms of ignition systems, transformers, kilocycles, and talking machines. He knows almost nothing about the meaning of these terms and very little about the use of them. As he develops he learns more about their application but very little more about their underlying principles. This situation is likely to continue throughout the educational system with its textbooks, workbooks, and laboratories, unless a better approach is made to the subjects. A few principles mastered are worth more than a great deal of miscellaneous information. A law or principle becomes abstract and meaningless too often and it is passed as a verbal expression (15).

The purpose of this study was, first, to design for use in schools, a group of models[1] that can be constructed by advanced students, faculty, or commercially. These models were designed to portray graphically and visually in three dimensions the principles and laws in question.

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[1]The meaning of the word model as used here is a representation of an abstract principle in a concrete form rather than a small replica of a piece of apparatus.

While the ideas stated above may apply to all branches of science, this research was limited to problems that are encountered in the study of physics. The second part was to develop a group of projects which may be used early in the elementary school and continued through the secondary school. These projects were designed to awaken the scientific interest in the exploratory age and to give a chance for expression in the creative age. The group has been selected as representative of projects for students of different grade and interest levels.

The sequence of these models and projects has been arranged according to the outline of subject matter in the order that is usually followed in physics textbooks. It was not intended that this group should be used as an outline course. Nevertheless, it may be found useful where models and projects are in demand, and may serve as a guide and inspiration for developing other projects. Although complete details have been given for these models and projects as used by the author, experience has shown that the greatest value was gained by the students who were able to plan their own problems.

The beginning of this program must start with the earliest stages of the learning process. This fact is very

well stated by the Kansas Committee for Improvement in Public Instruction,

> The kindergarten is not too early to teach to the child orderliness, to base judgments on facts, and to begin to listen for reasons underlying puzzling things that come into life. A young child wants a direct answer to his questions--short, concise, true; he does not understand the many reasons given him by adults, because his immature mind cannot take them in. This small beginning will lead naturally to the attitude of considering suggestions, new points of view, and the scientific attitude of pondering on, "I wonder why" then becomes early a method of thought. With growth will come the knowledge that there is an orderly way in nature of doing things that when followed will lead to definite conclusions, an orderly way of making a kite, or preparing a lesson, or reading a book. This young person who has the scientific attitude will go far in understanding life about him, and be able to select workable ways of doing things--a young scientist.

Consequently the projects for the elementary school were designed to fulfill two requirements. First, they must arouse interest. This was not difficult as the child of this age is very curious. He is alert to new ideas, especially projects of a mechanical nature that he can build, manipulate and arrive at the principle. The second requirement was that it must be exploratory in nature. This required a variety of simple projects that could be prepared and mastered in a short interval. Since the projects were offered primarily to develop an appreciation of physics and to create a desire to know more about the under-

lying principles, they were simple in construction, inexpensive, and required only the simplest tools to build them.

The work can be introduced to students in various ways. One is through a special organization that meets after regular school hours, Saturday or any specially arranged time. This group should be voluntary, and interest should be spread by the nature of the work. "Overhead activities" and organization should be reduced to the barest minimmm to avoid confusing the principal interest of the group (10). The development of this program should receive the hearty support of the home, school, and community.

This program can be introduced to the elementary schools in another way which is very effective. This is to make the work supplementary to the regular school curriculum. A course in science in the curriculum of the middle grades is certainly not recommended. However, with the new plan for social studies and newer development in "Improvement of Instruction" under the direction of Miss Dale Zeller, sponsored by the State Department of Education and Kansas State Teachers Association, there is an excellent opportunity to give the group experience in areas to be explored (21). The idea is stated well in the quotation

taken from the report of the committee working in the curriculum laboratory (27),

> Verbal learning about situations is inadequate; therefore, the school community will provide opportunities for learning from first hand situations, first hand contacts with nature, contact with technological processes and working with materials other than symbols. In such a school experience with processing, building, modeling, construction and painting are as necessary as experiences with symbols.

METHODS

The design of the models was a result of a study made of the diagrams, pictures, and discussions of the principles as presented in the standard textbooks. An attempt was made to make the models as nearly as possible a representation of the principle or law involved, and in such a way that they could be used to study the principles, laws, rules, or theories that are associated with it. The parts used were shaped as nearly as possible to represent the conventional diagrams used in the explanation of the subject. Contrasting colors were used to make possible a better conception of each factor involved and to show their interrelationship. When several related models formed a group, the same color scheme was used throughout.

The projects were designed to meet a demand for special apparatus. This was accomplished by determining the principle involved, investigating the work of others,

considering materials available and means of construction, and then by assembling these ideas and designing the project. The laboratory apparatus was planned so that it would supplement equipment already on hand for laboratory experiments or to present a scientific problem in a different way. The demonstration apparatus was designed to give a greater number of ways of applying the ideas in an easily comprehensible manner. The individual or group projects were designed to meet special needs that arose from time to time. In all cases an attempt was made to keep the problems simple from the standpoint of construction and application so that they could be used as class or individual projects that would appeal to students. The designs employed were ones which could be made with a minimum of expense and shop facilities.

A FEW SUGGESTIONS FOR CONSTRUCTION

A few suggestions about special methods and materials that can be used in the construction of projects and models may be helpful. The problem of making threads for special fittings is usually a serious one since most elementary shops and laboratories are not equipped with tap and die sets. In most cases this difficulty can be overcome by selecting a bolt and nut of the desired size,

EXPLANATION OF PLATE I

Fig. 1. An arrow made from a glazier point.

Fig. 2. An adjustment screw made from a washer and stove bolt.

Fig. 3. A thumb screw made from a washer and stove bolt.

Fig. 4. (A) Mounting threads on the end of an object.
(B) Mounting threads on the side of an object.

Fig. 5. A substitute for a spring.

Fig. 6. A reflector made from a funnel.

Fig. 7. A diagram for an adjustable bearing.

Fig. 8. A suggestion for mounting lenses.

Fig. 1

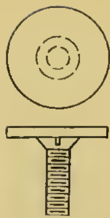


Fig. 2

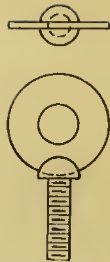
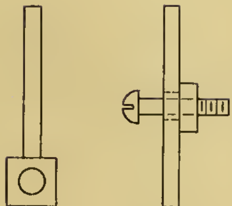


Fig. 3



A B

Fig. 4

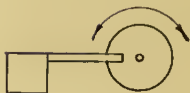


Fig. 5

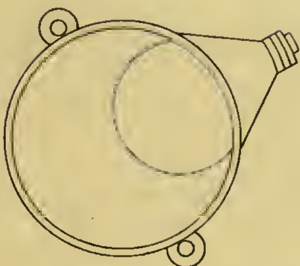


Fig. 6

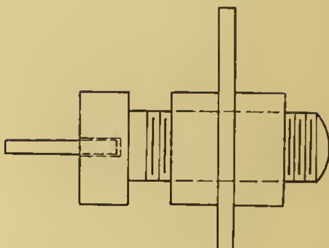


Fig. 7

Fig. 8

shaping the bolt and sholdering the nut in position for the threaded hole (Plate I, Fig. 4 A). If the hole is to be through a piece of metal, the hole can be drilled slightly larger than desired and the nut soldered over the hole (Plate I, Fig. 4 B). Copper tubing as used for gas lines for automobiles is useful in making a helix for models and any place where small pipe is required. Arrow heads for models can be made quickly by getting a box of glaziers points and filing out one side to the desired shape (Plate I, Fig. 1). Brass or copper rods are usually hard to get in most communities and it is quite expensive to order in small quantities. Whenever it is not desirable to use iron for construction, suitable brass rods in varying sizes can be obtained from welding shops. Lucite is a transparent solid substance that can be worked into shape with common tools. It is manufactured in a variety of forms including rods, tubes, solid cylinders, rectangular blocks, and sheets. Magnets, connectors, special fittings, and miscellaneous parts can often be found in the discard pile of telephone companies, garages, radio shops, and machine shops. Old discarded mechanical and electrical toys are usually a good source of parts. Clock springs, hacksaw blades, files, and needles are good grades of

steel that can be magnetized. When new parts are desired, hardware stores, variety stores, electrical shops, and supply houses can readily supply needs in any quantities.

There are many types of instruments that need special parts such as winged nuts, adjustment screws, special lock nuts, and adjustable bearings. Plate I, shows a group of home constructed parts that will serve many needs. Figures 2 and 3 of Plate I represent adjustment screws and thumb screws made by soldering a washer to the head of a suitable bolt. In many cases, where springs are needed they can be replaced by a weight (Plate I, Fig. 5). A reflector for illuminated signs and house numerals can be made from funnels or baking pans as illustrated in Fig. 6, Plate I. An adjustable bearing can be made by drilling a hole in the head of a machine bolt which is held in position by two lock nuts as illustrated in Fig. 7, Plate I. Figure 8, Plate I, shows a method of mounting lenses for telescopes and other optical instruments. This was done by making a tube from sheetiron, soldering a ring of wire in one end then spacing the lens by cutting a piece of flexible cardboard the length of the desired spacing, rolling it into a cylinder and sliding it into place. Electric motors from small electric fans are suitable for light work and may often be used to replace electromagnets.

They have the advantage of being cheap, ready to use, and can be operated directly on 110 volt, A.C. circuits. Platinum points for electrical contacts may be taken from automobile breaker points and soldered into place.

A THREE DIMENSION PUZZLE

The three dimension puzzle is not so much a puzzle as a device for introducing the idea of the three dimensions of space. However, the student enjoyed making and demonstrating it since it was in the form of a puzzle.

List of Materials

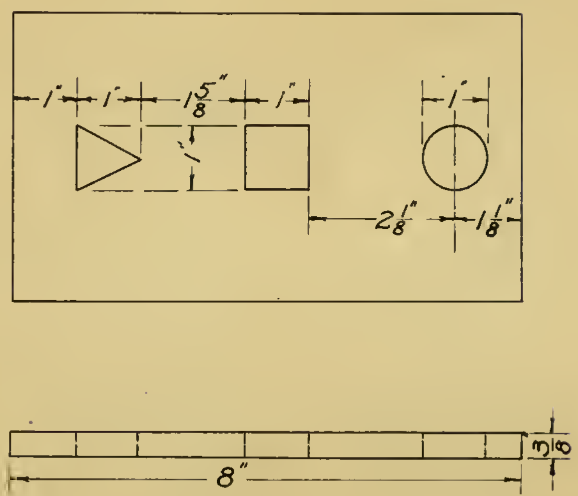
1 plywood board	3/8" x 4 1/2" x 8"
1 block of wood	1" x 1" x 1"

Three holes were cut in the board in the form of a triangle, a circle, and a square (Plate II, Fig. 1). The problem was to cut one plug that would exactly fit each of the three holes. The solution is shown in Fig. 2, Plate II. Care was taken to have the altitude of the triangle, the side of the square, and the diameter of the circle equal. The problem can be varied by changing the square to a rectangle and adjusting the altitude of the triangle accordingly.

EXPLANATION OF PLATE II

Fig. 1. Working drawing for a three dimension puzzle.

Fig. 2. Working drawing for the key to the puzzle.


1"
1"
$1\frac{5}{8}$"
1"
1"
1"
$2\frac{1}{8}$"
$1\frac{1}{8}$"
8"
$\frac{3}{8}$

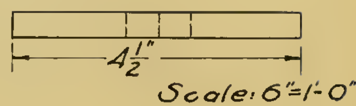

$4\frac{1}{2}$"
Scale: 6"=1'-0"

Fig. 1

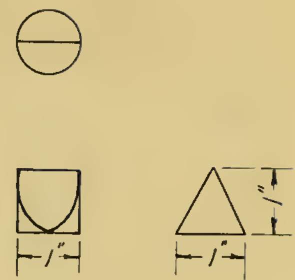

1"
1"
1"

Fig. 2

GRAVITY DEFYING APPARATUS

The question arises as to what is wrong when something happens which apparently cannot happen. The project shown in Fig. 1, Plate IV, worked in just this way. Two nonparallel bars were arranged in such a way that when a cylindrical roller was placed at one end of the bars it rolled to the other end but when a tapered roller was placed on the bars it rolled in the opposite direction. This made a good problem for a demonstration of the relative position of the center of mass of an object.

List of Materials

2 hardwood blocks	3/4" x 3/4" x 10"
2 hardwood blocks	3/4" x 3/4" x 6"
1 hardwood block	2" x 2" x 6"
1 glass tube	1/4" x 2"
4 small finish nails	

The parts were cut out and assembled as shown in the working drawing in Fig. 1, Plate III. The dimensions of the tapered roller are clearly marked in Fig. 2, Plate III. The construction of this problem was primarily a problem in elementary woodwork and it made a good correlation problem between the shop and science classes.

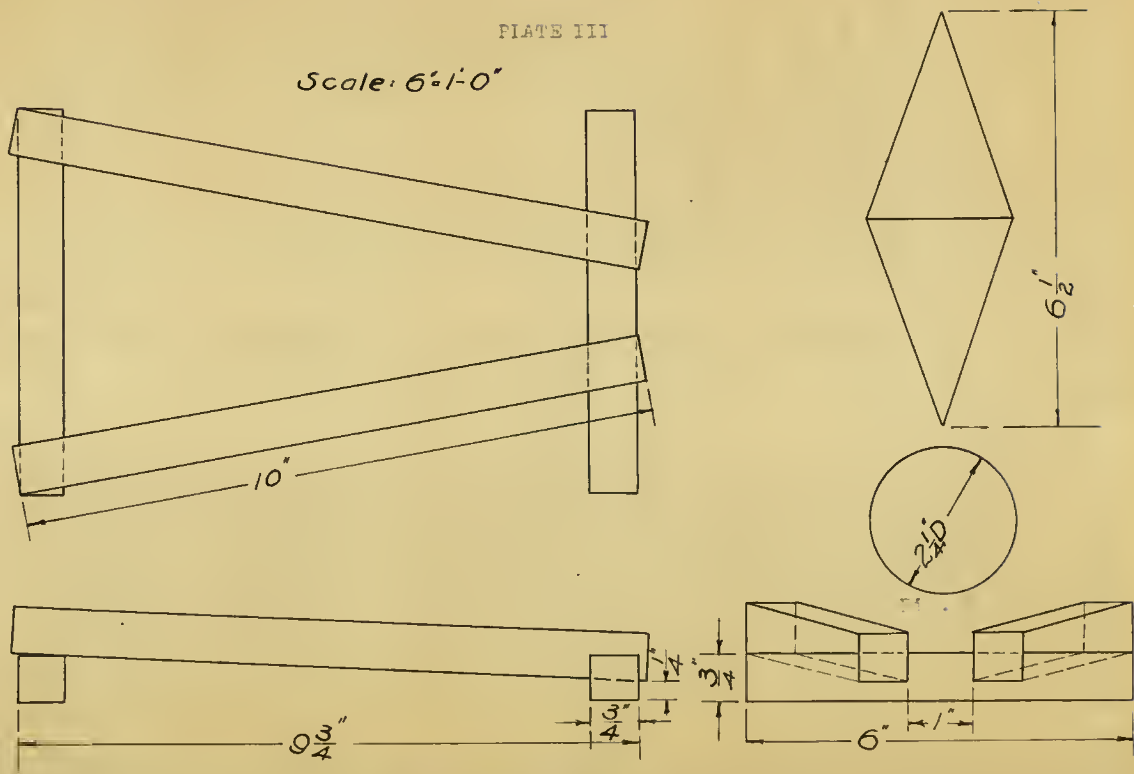
EXPLANATION OF PLATE III

Fig. 1. Working drawing of the gravity defying apparatus.

Fig. 2. Working drawing of the tapered roller.

PLATE III

Scale: 6" = 1'-0"



EXPLANATION OF PLATE IV

Fig. 1. Gravity defying apparatus and three dimension puzzle.

Fig. 2. A carbide cannon.

Fig. 3. Combination apparatus used as an incline plane.

Fig. 4. Combination apparatus used as a lever.

PLATE IV

Fig. 1

Fig. 2

Fig. 3

Fig. 4

CARTESIAN DIVERS

The cartesian diver was a simple and interesting project which had a number of variations. Plate V shows a few ways that this project has been used. Figure 1, Plate V shows one of the simplest forms.

List of Materials

1 wide mouth bottle with stopper
1 small glass vial

The wide mouth bottle was filled with water and the vial was filled about one half full of water. Then the vial was inverted in the bottle and the amount of water inside the vial was varied until it would just float. The diver was sent to the bottom by pressing on the cork and returned when the pressure was released. When the students became familiar with the principle that caused the diver to work, they wanted to try out their own ideas.

THE LUNGOMETER

Many devices have been arranged for measuring the capacity and strength of the lungs. The apparatus is usually built in separate units and in a temporary manner. The project shown in Plate VI, is an arrangement of these

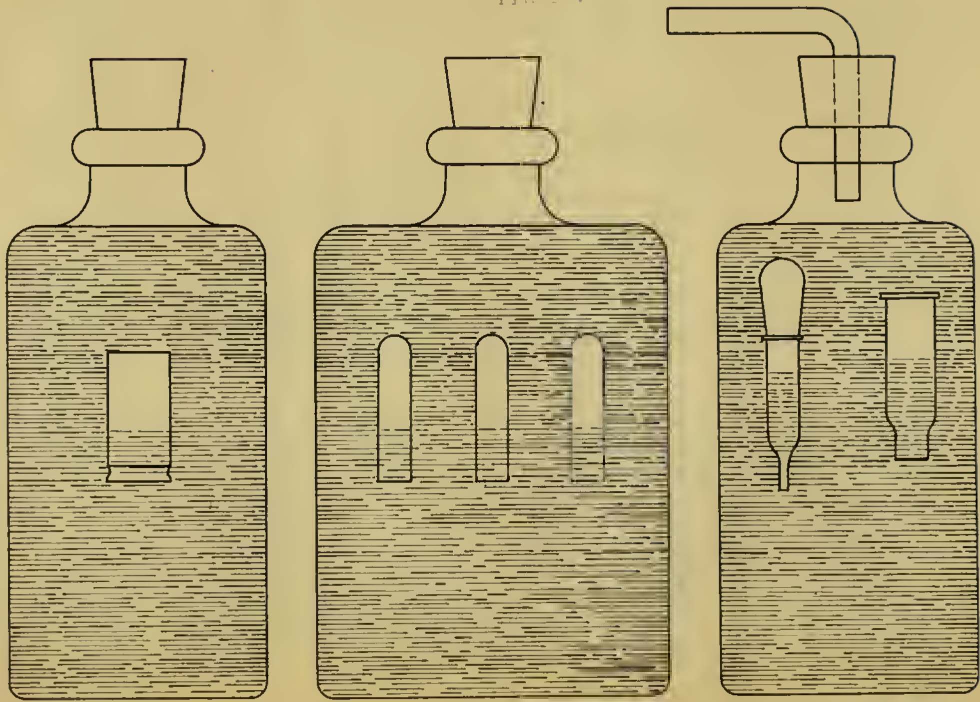
EXPLANATION OF PLATE V

Fig. 1. Cartesian diver operated by pressing the cork.

Fig. 2. Cartesian diver operated by pressing the bottle.

Fig. 3. Cartesian diver operated by blowing into the bottle.

PLATE V



EXPLANATION OF PLATE VI

Fig. 1. Working drawing of the lungometer.

Fig. 2. Perspective view of the lungometer.

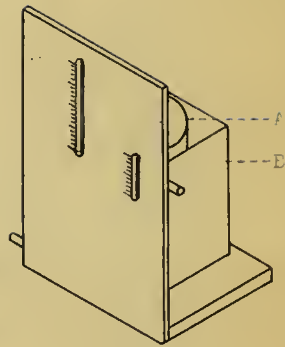


Fig. 2

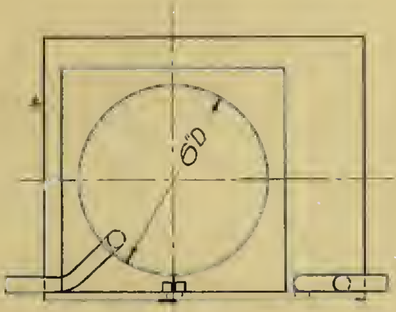
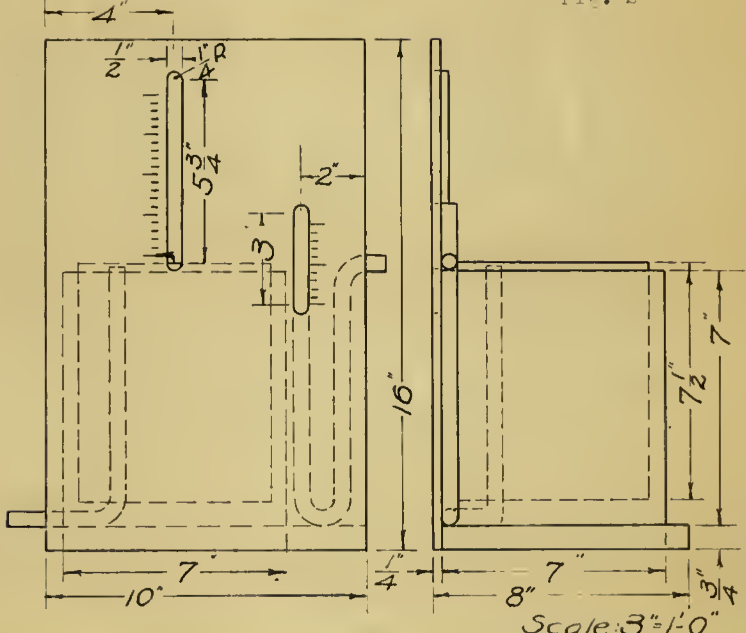



Fig. 1

two instruments combined into one permanent piece of equipment which can be calibrated to give readings in actual units.

List of Materials

1 plywood board	1/4" x 10" x 16"
1 pine board	3/4" x 8" x 10"
1 glass tube	3/16"x 20"
1 copper tube	1/4" x 14"
1 No. 12 iron wire	12"
1 gallon can	
1 square can slightly larger than the gallon can	
1 small eye screw	
small quantity of mercury and colored water.	
2 No. 9 F.H. 1 1/2" wood screws	
4 No. 8 R.H. 3/4" wood screws	
small strips of tin with screws for mounting tubes	

The parts were arranged as shown in Fig. 1, Plate VI. The panel was mounted on the base board, then the oil can B was put in place and fastened by two screws through the top edge and into the back of the panel. The length of copper tubing was bent to shape and mounted through a small hole in the bottom edge of the side of the oil can. The tube was soldered in place. This closed the hole in the can. A guide made of the iron wire was mounted on the back of the panel so the guide was one half inch directly behind the opening of the volume guage and parallel to it. The gallon can A was inverted in the square oil can and a small eye screw soldered to the top edge in such a way

that the guide wire would go through the eye screw. Another short piece of wire was soldered to the end of the inverted can beside the eye screw so that it extended through the opening in the panel. This wire was bent at right angles on the front side of the panel and an arrow soldered to the end of it. This served as the indicator on the volume scale. When air was forced into the inverted can through the copper tube the can rose and the indicator showed the height it rose which was proportional to the volume.

The pressure gauge was merely an open manometer tube mounted on the back of the panel in such a way that the variation of the liquid in the open tube was shown through an opening in the panel. The tube was filled with just enough mercury to cause it to operate satisfactorily, then colored water was added to the mercury on the scale side of the tube. This reduced the amount of mercury needed for the apparatus and also made it easier to read.

The construction of this useful project was an interesting problem. The knowledge required to calibrate the scales on each gauge was sufficient to make the calibration an excellent exercise in physics.

INCLINE PLANE AND LEVER APPARATUS

A problem that often arises in laboratory management is the storage of equipment. Often, apparatus is used only once and then is stored away for another year. The project illustrated in Figures 3 and 4, Plate IV, combined two pieces of apparatus and was designed so that it could be taken apart and stored in a compact kit. The convenient size of the project made it suitable for both the regular laboratory procedure and for the lecture demonstration method.

List of Materials

1 hardwood board	1"	x 4"	x 24"
1 hardwood board	1/2"	x 4"	x 25"
1 hardwood board	1 1/2"	x 1 1/2"	x 9"
1 hardwood board	1/2"	x 2"	x 5"
3 24 gauge sheet metal			
2 No. 9 F.H. 1 1/2" wood screws			
1 large nail			

This project is illustrated in Fig. 1, Plate VII. The base board was cut to the proper dimensions, then the corners and edges were slightly rounded. The vertical standard was attached to the base by the machine bolt countersunk in the bottom of the base. It was fastened by a nut set in a hole drilled from one side of the

EXPLANATION OF PLATE VII

Fig. 1. Working drawing for the incline plane and lever apparatus.

Fig. 2. The combination incline plate and lever apparatus assembled for storage.

Fig. 3. Support for attaching the weights and spring balances.

PLATE VII

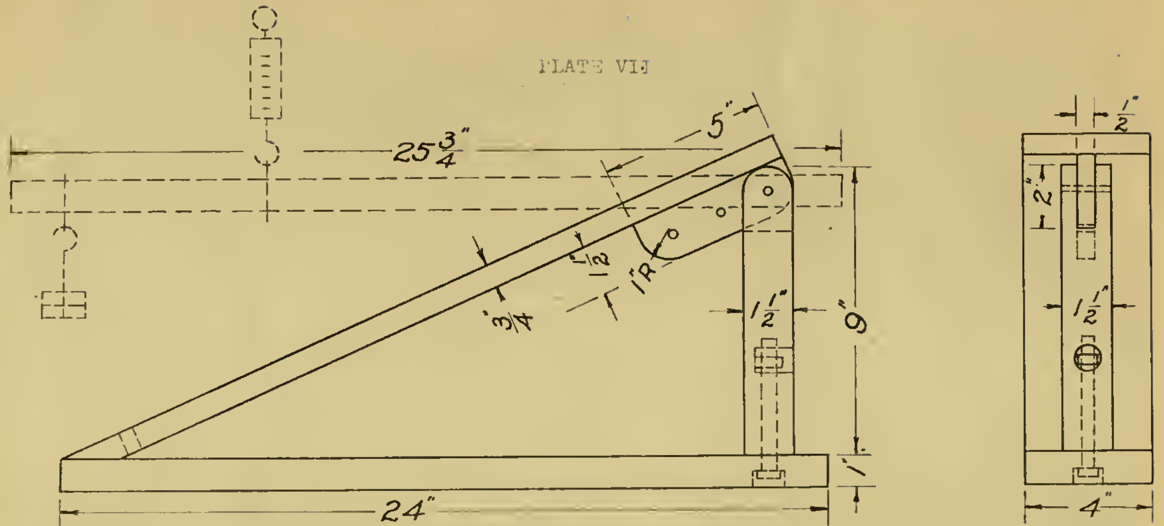
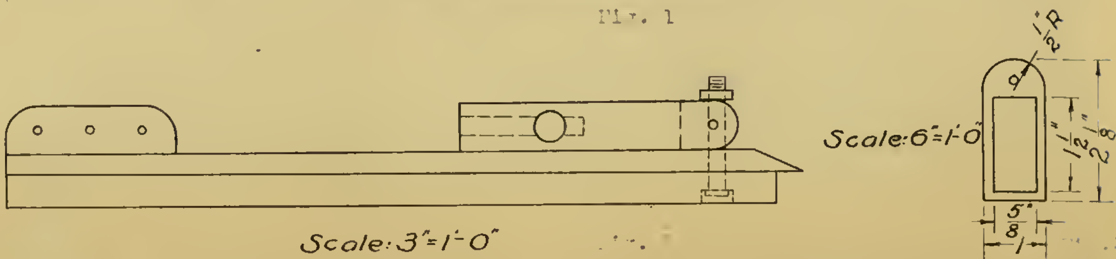


Fig. 1



Scale: 3"=1'-0"

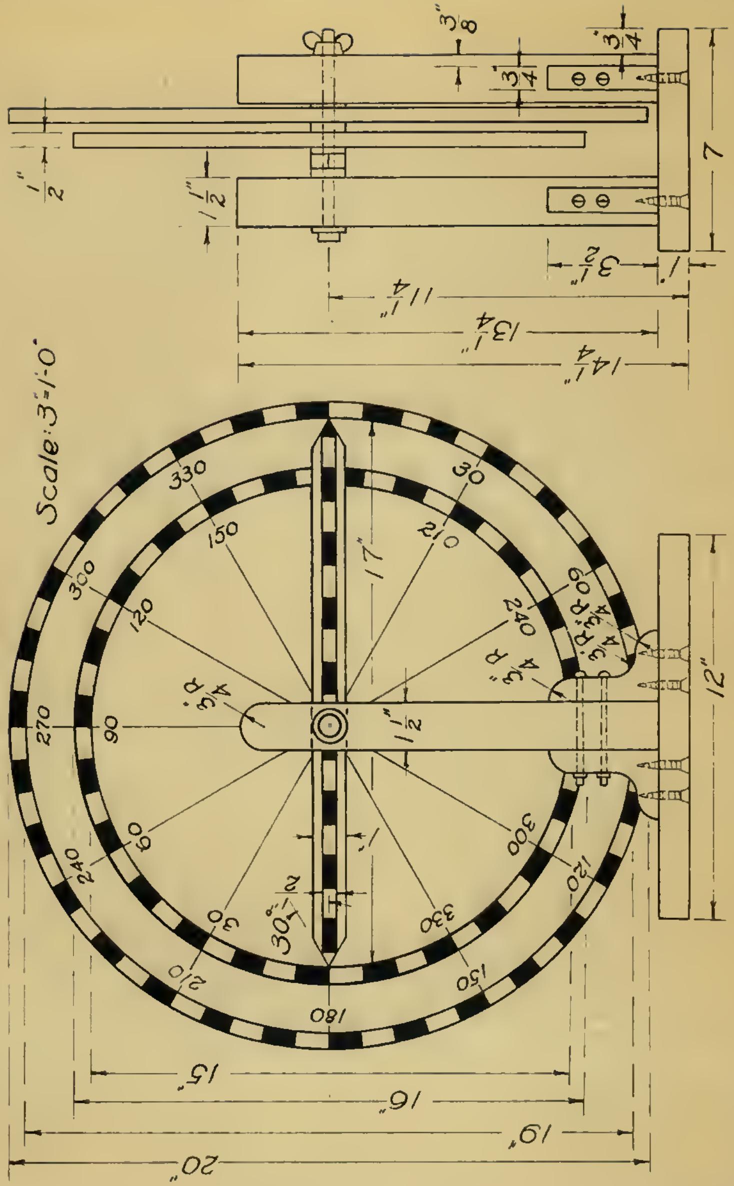
standard. This gave an extra rigid support and one which could be taken apart quickly. The top end of the standard had a slot which was used as a fulcrum for a lever and as a recess in which the incline plane was attached. The drawing in Fig. 1, Plate VII, shows the equipment set up as an incline plane and the broken lines illustrate the use of the lever attachment. Convenient supports for attaching the weights and spring balances to the lever arm are shown in Fig. 3, Plate VII. Figure 2, Plate VII, shows the apparatus assembled for storage.

LECTURE TABLE APPARATUS FOR MECHANICS

The introduction to the study of mechanics is associated with many terms, some of which are work, moments of force, angular velocities, lever arm, efficiency, rim speed, and speed ratios. This work can be explained by use of blackboard illustrations but much time can be saved by using apparatus as shown in Plate VIII. This equipment was not difficult to construct and it made an excellent problem correlating science, geometry, and manual training.

EXPLANATION OF PLATE VIII

Working drawing for the lecture table apparatus for mechanics.


Scale: 3"=1'-0"
3/8"
3/4"
3/4"
1/2"
1 1/2"
7
3 1/2"
1"
11 1/4"
13 1/4"
14 1/4"
17"
1 1/2"
12"
4 1/2" R
3" R
1"
30°
1/2"
15"
16"
19"
20"
330
30
150
210
300
60
120
240
270
90
180

List of Materials

1 hardwood board	1"	x 7"	x 12"
2 hardwood boards	1 1/2"	x 1 1/2"	x 13 1/4 "
4 hardwood boards	3/4"	x 2 1/4"	x 3 1/2"
1 plywood board	1/2"	x20"	x 20"
1 plywood board	1/2"	x15"	x 15"
1 sheet of poster cardboard		20"	x 20"
1 sheet of poster cardboard		15"	x 15"
4 carriage bolts		1/4"	x 5"
1 stove bolt with wing nut		3/8"	x 6"
8 No. 9 F.H. 2" wood screws			
1 hardwood stick	1/2"	x 1"	x 17"

Plate VIII shows the working plans for constructing this project. The two standards were attached to the base and were braced by means of two corner braces. The divided circles were marked out and inked with black India ink on a sheet of poster cardboard. These were cut out and glued to the circular discs which were mounted between the upright supports by means of a machine bolt secured by a thumb screw. The lever, which was free to rotate, could be locked in position by tightening the wing nut on the back of the apparatus. A small nail, with its head filed off and then pointed, was driven into each end of the pointer. The frame of this apparatus was enameled black but the discs, with their contrasting black on white, needed no additional finishing.

A CARBIDE CANNON

A novelty in the form of a toy is helpful in getting the attention of the group focused preparatory to the presentation of a new principle. The students were anxious to attempt an explanation after the cannon illustrated in Fig. 2, Plate IV, was set up and fired. This machine was useful in the discussion of the gas engine. The ignition system, spark-plug, gas mixtures, and burning of gas to produce power were exemplified when the apparatus was operated.

List of Materials

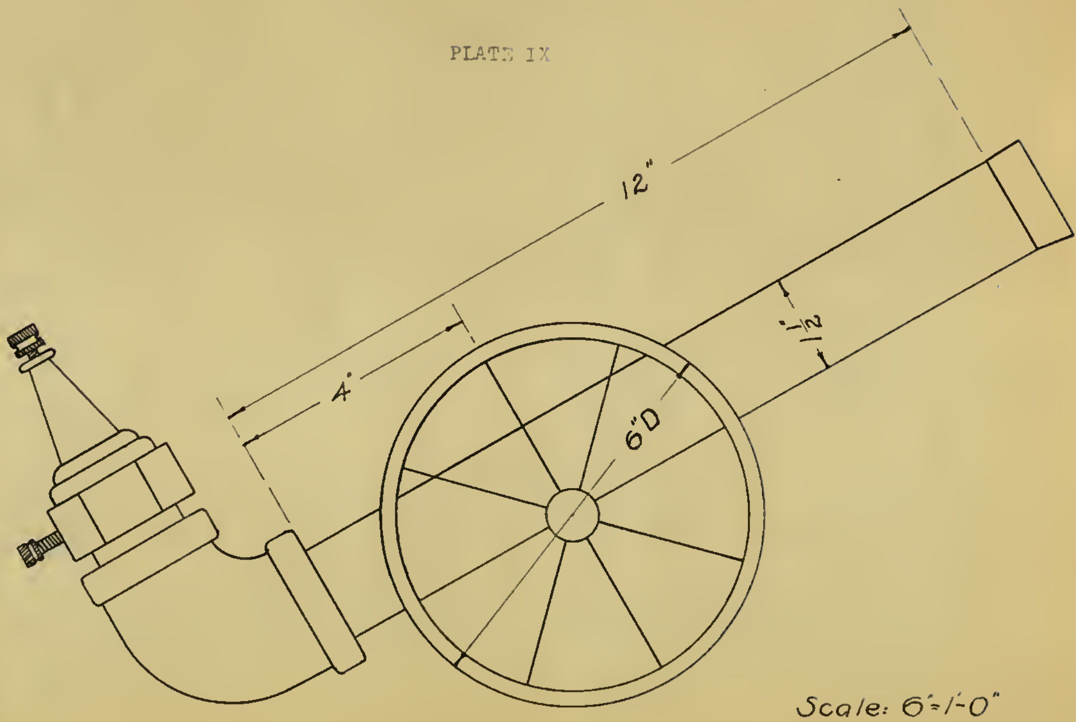
1 gas pipe	3/4" x 12"
1 spark-plug	11/16" base
1 elbow	3/4" x 3/4"
1 pair of wheels	6" diameter
1 battery connection	
1 cork	
1 No. 9 iron wire 6" long	

The gas pipe and elbow were assembled as shown in Plate IX, and, the spark-plug was screwed into the elbow. Since the threads of the spark-plug were a different type from those of the elbow, the spark-plug was forced as far as possible. Then it was soldered securely in place to make it safe for use. Toy wheels are suitable for mounting the cannon, but can lids which were fastened to a piece

EXPLANATION FOR PLATE IX

A working plan for a carbide cannon

PLATE IX



of number nine wire soldered to the gas pipe served the purpose very well. The cannon was operated by placing a few drops of water in the barrel; then a small piece of calcium carbide was dropped in; the cork was inserted; and then, after waiting about five seconds; the ignition switch was pressed.

HERO'S ENGINE

Hero's engine is important because it was one of the first attempts made to convert heat energy into mechanical energy. It made a good project because of its simple construction, low cost, and the principle involved.

List of Materials

1 1/2 gallon syrup pail	
1 tall milk can	
2 copper tubes	1/4" x 6"
2 copper tubes	1/4" x 3/4"
2 small washers	

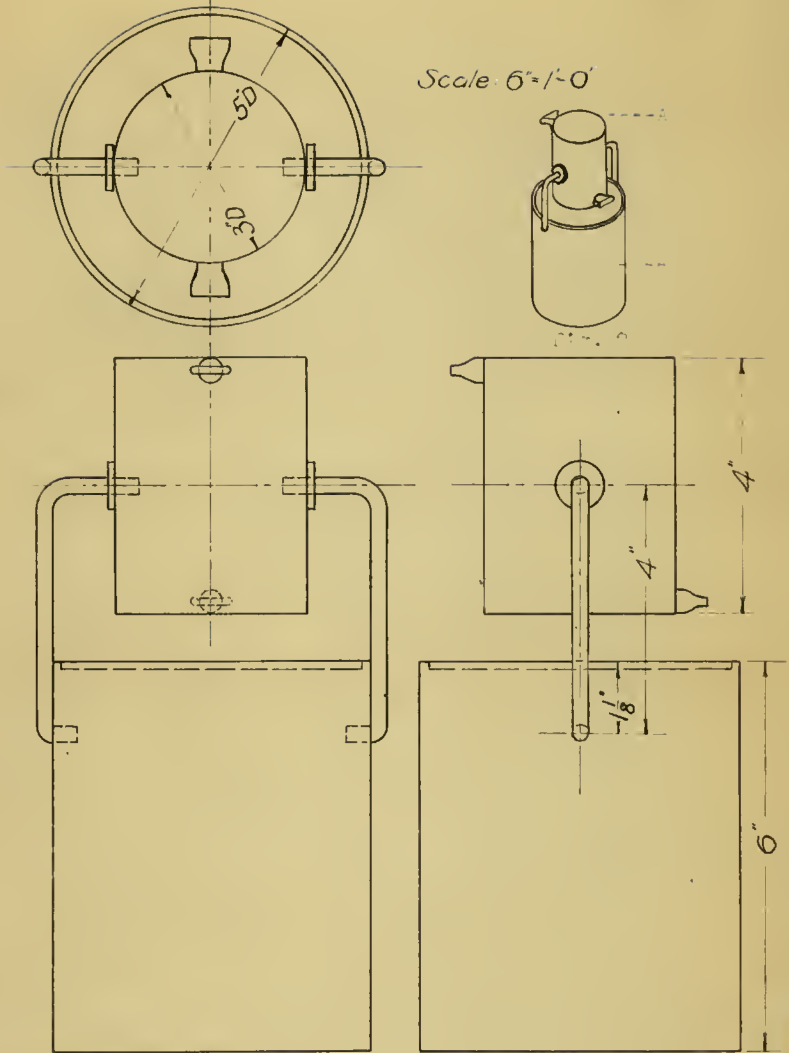
Figure 1, Plate X gives the dimensions for this problem, and, a perspective view is shown in Fig. 2, Plate X. A hole was drilled through the syrup pail B at the place where the bail had been removed. The longer copper tubes were bent to shape and soldered into the holes (Plate X, Fig. 1). Then two holes were drilled in the center of the

EXPLANATION OF PLATE X

Fig. 1. Working drawing for Hero's engine.

Fig. 2. Perspective view of Hero's engine.

Scale 6" = 1'-0"



side of the milk can A opposite each other. Washers were soldered to the copper tubes, where they entered the milk can, to serve as guides. The shorter pieces of tubing were flattened slightly at one end to form a flat jet, and the other end of each was placed in holes drilled opposite each other near the top and bottom ends of the milk can. The completed project was safe to use because the lid of the pail served as the safety valve.

A HYGROMETER

The hygrometer is an instrument that many schools do without because it is relatively expensive in proportion to the uses made of it. The development of air conditioning is placing a great deal of emphasis on humidity, and consequently, the hygrometer is becoming an essential article of the home and business house. Plate XI shows the working plan for building a hygrometer which was constructed by students.

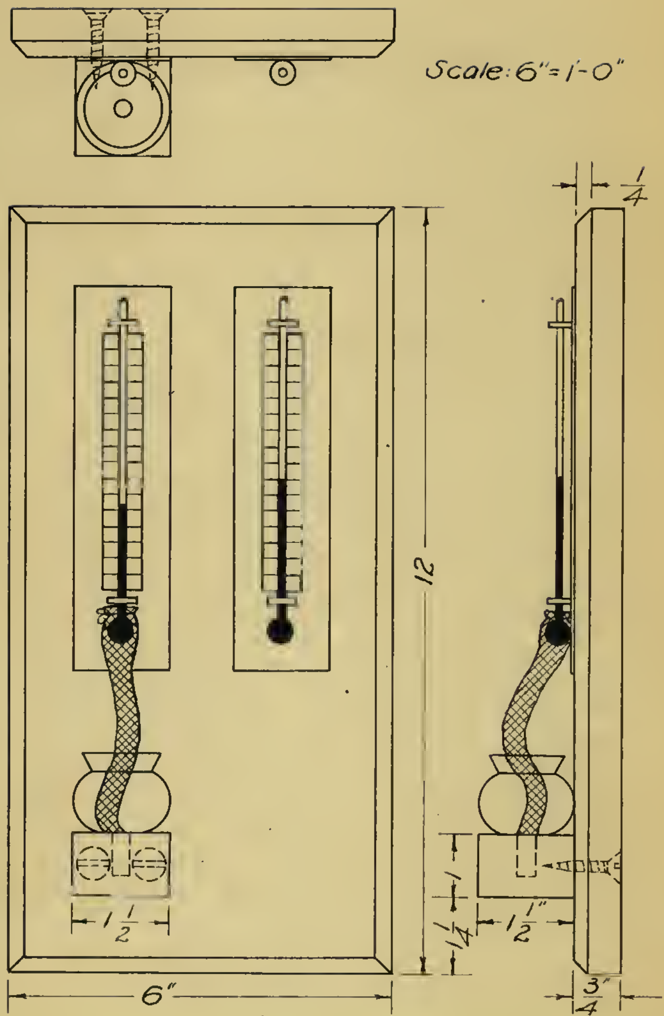
List of Materials

1 walnut board	3/4" x 6" x 12"
1 walnut block	3/4" x 1 1/2"x 1 1/2"
2 No. 9 F.H. 1 1/2" wood screws	
2 matched thermometers	
1 top from a thistle tube	
1 toy lamp wick	

EXPLANATION OF PLATE XI

A working drawing of a student built hygrometer

PLATE



The walnut board was cut to dimension. The matched thermometers were glued to the walnut board so that they were uniformly spaced from the top and sides of the walnut board. The small walnut block was fastened two and one half inches below the left thermometer. One end of the toy lamp wick was tied to the bulb of this thermometer and the other end was placed in the bowl of the thistle tube which was supported by the small walnut block. The thistle tube was filled with water after the parts were assembled. The relative humidity was determined by referring the data taken from the hygrometer to a relative humidity table.

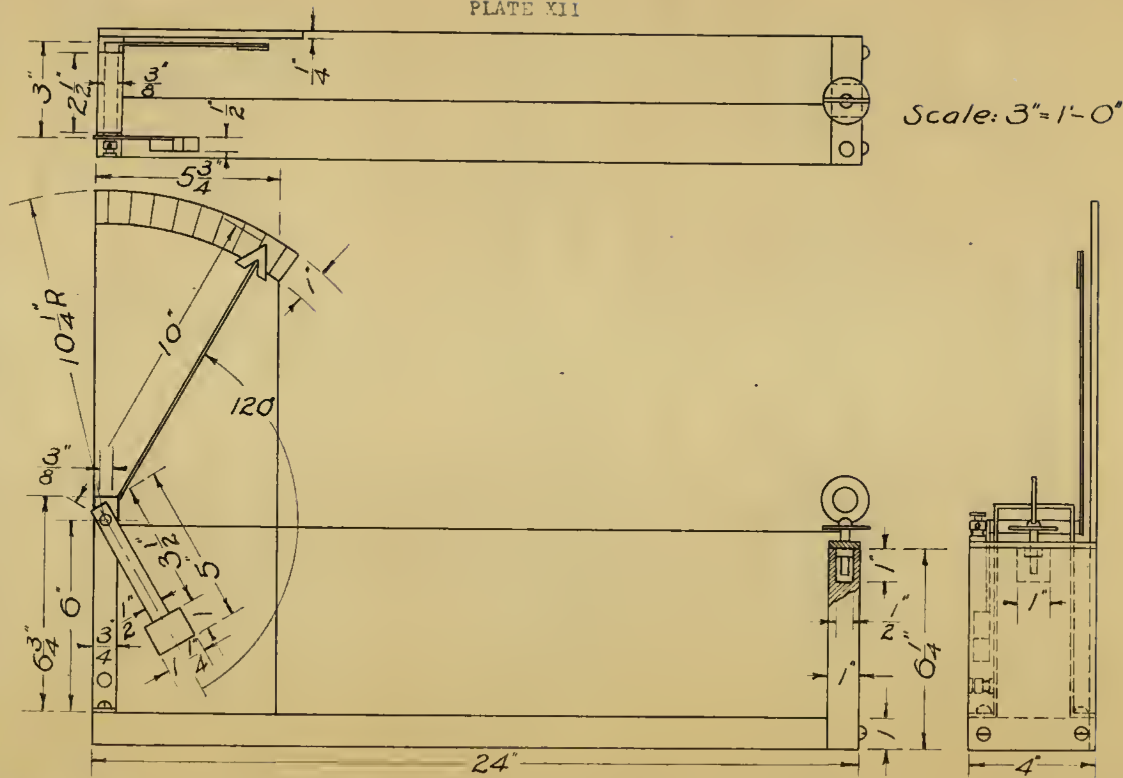
LINEAR EXPANSION APPARATUS

Equipment found in the high school physics laboratory for studying the expansion caused by heat usually consists of apparatus for determining the coefficient of linear expansion, ball and ring, unequal expansion bar, and thermostat. The project shown in Plate XII was designed to demonstrate linear expansion due to direct heating and also from heating caused by electricity. This combination made it possible to show the principle of a hot wire ammeter.

EXPLANATION OF PLATE XII

Working drawing for an apparatus for demonstrating linear expansion.

PLATE XII



List of Materials

1 hardwood board	1"	x 4"	x 23"
1 hardwood board	1"	x 4"	x 6 1/4"
1 plywood board	17 1/4"	x 7"	x 18"
1 brass strip	1/8"	x 3/4"	x 15 1/2"
1 brass strip	1/8"	x 1"	x 4"
1 brass strip	1/8"	x 1/2"	x 5"
1 stove bolt	5/16"	x 1"	
1 brass rod	3/8"	x 3"	
4 washers	5/16"		
1 No. 12 wire	12"		
2 No. 8 R.H. 1" wood screws			
4 No.10 R.H. 2" wood screws			
4 No. 8 F.H. 1" wood screws			
2 binding posts			
1 iron or brass weight			
1 glazier point			
1 30 gauge wire			

The end board was attached to the base board and the long brass strip was bent to shape. This was attached to the other end of the base as shown in Plate XII. A three-eighths inch hole was drilled in the center of the four inch brass strip and the three-sixteenths inch nut was soldered to the bottom side under the hole as shown in Fig. 4, Plate I. This strip was fastened to the top of the end board with screws. The two washers were soldered to the stove bolt to make a thumb screw with a flange. This was screwed into the top plate of the end board to serve as an attachment for the wire specimen. The rod was

placed horizontally through holes in the bracket at the left end of the apparatus. The number twelve wire was soldered to one end of the brass rod, forming the pointer arm. The five inch brass strip was soldered to the other end of the brass strip forming the lever arm for the weight. Washers were placed between the lever arm and weight arm, and the bracket so as to give them the proper spacing. The plywood was cut out and a scale made on paper was glued to it. This was fastened to the back of the base by two screws. The binding posts were soldered to the bracket at one end and the brass plate at the other end of the apparatus to make connections for the electric current. A one-fourth inch pin was soldered to the center of the rod and perpendicular to it.

A loop in the end of the wire to be tested was placed over the pin on the brass rod and then the wire was wrapped around the rod counterclockwise two or three times. Then, it was stretched across the apparatus until the pointer was in a perpendicular position. The thumb screw was tightened to hold it in position. The sensitivity of the instrument made it a convincing demonstration.

COMBINATION COMPASS AND DIP NEEDLE

There is probably no instrument that is more useful in the elementary study of magnetism than a combination compass and dip needle similar to the one shown in Fig. 1, Plate XIX. The apparatus can be used individually for experiments as well as for lecture table demonstrations. Its simplicity of design as shown in Plate XIII and its usefulness appealed to students as a project.

List of Materials

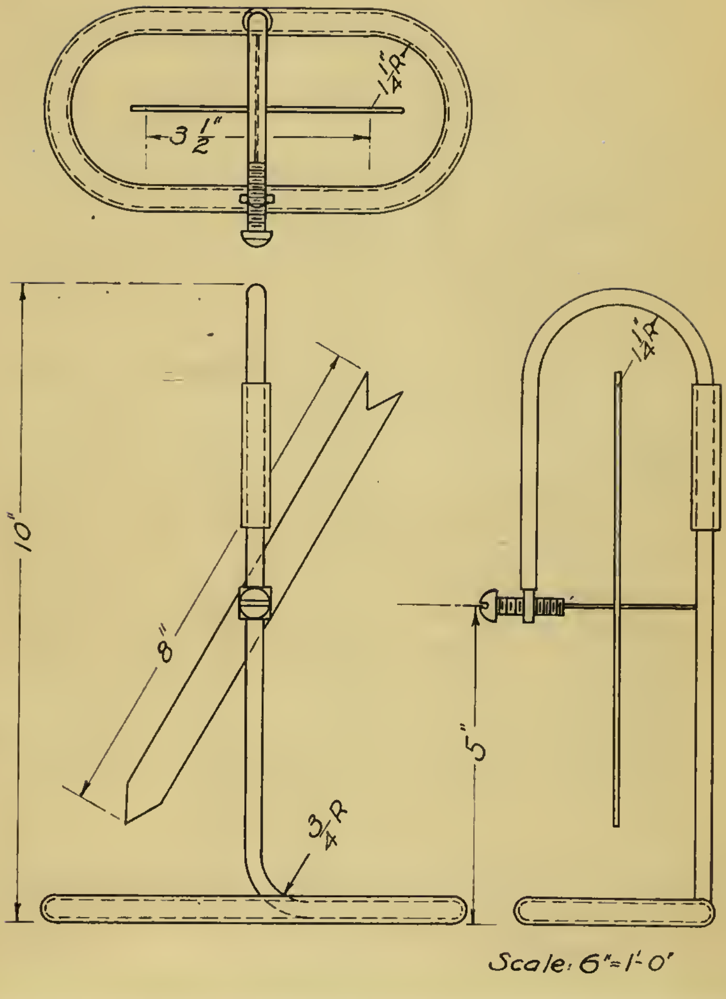
1 brass or iron rod	1/4"	x	30"
1 rubber tube	1/4"	x	15"
1 rubber tube	1"	x	2"
1 R.H. stove bolt	3/16"	x	1"
1 hacksaw blade or clock spring			
1 large darning needle			

The rod was bent to shape according to the dimensions given in Plate XIII. The long rubber tube was forced over the part of the rod forming the base of the frame. The short piece was placed on the long vertical rod near the top. These rubber tubes were used merely for a cushioning effect and to make the apparatus quiet in use. The nut was soldered to the end of the short vertical rod (Plate I, Fig. 4). Care was taken to get the nut placed

EXPLANATION OF PLATE XIII

Working drawing for a combination compass and dip needle.

PLATE XIII



so that the bolt was perpendicular to both supporting rods. The compass needle was made from a light weight piece of highly tempered steel. A hole was made in the steel for the shaft by using a center punch. The compass needle was shaped by filing. The darning needle was soldered through the hole perpendicular to the plane of the compass needle. The bearings were made by drilling a hole into the inside of the back support and a hole in the end of the stove bolt. The compass needle was accurately balanced before it was magnetized. When the project was assembled and enameled, it made a useful addition to the school laboratory.

A GROUP OF ELECTROMAGNETIC MODELS

The group of electromagnetic models, as shown in Plate XIV, was designed for class lecture purposes to be followed by individual inspection. The models helped the student get a better conception of the relation of the magnetic field to the current carrying conductor. The application of the rules and principles was made visible in three dimensional forms, thus making a concrete example upon which learning was based (13). This gave the student the opportunity of learning through the three main channels; seeing, hearing, and operationally experiencing

EXPLANATION OF PLATE XIV

Fig. 1. Electromagnetic model No. I.

Fig. 2. Electromagnetic model No. II.

Fig. 3. Electromagnetic model No. III.

Fig. 4. Electromagnetic model No. IV.

PLATE XIV

Fig. 1

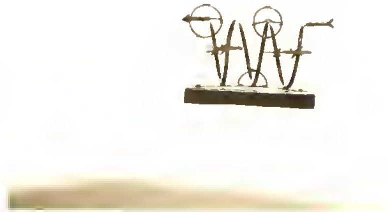


Fig. 2

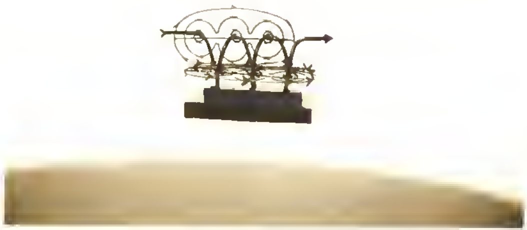
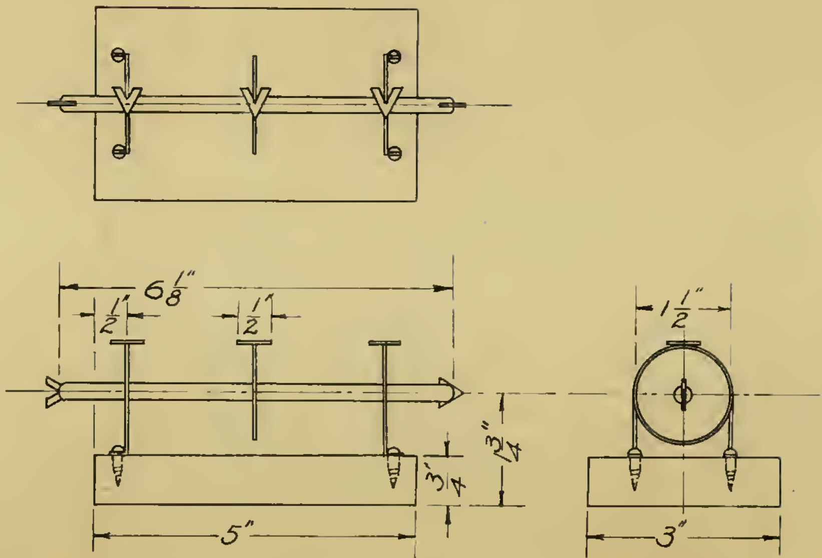


Fig. 3

Fig. 4

EXPLANATION OF PLATE XV

Working drawing for the electromagnetic model No. 1.



Scale: 6"=1'-0"

the ideas that were presented (19).

The models were made of iron wire mounted on wooden bases. Arrows were mounted on the wires to indicate the direction of the electric current and magnetic lines of force. A conventional color scheme was used throughout the group. Red was used for the electrical conductors, green for the magnetic flux, and black for parts not involved in the principles displayed.

List of Materials

2 pine blocks	3/4" x 3 1/4"	x 3 1/2"
2 pine blocks	3/4" x 3"	x 6"
1 pine block	3/4" x 3 1/2"	x 6"
1 pine block	3/4" x 3"	x 5"

4 No. 9 F.H. 1 1/2" wood screws
2 No. 8 F.H. 1" wood screws
4 No. 6 R.H. 1/2" wood screws
8' No. 4 galvanized iron wire
20' No. 16 galvanized iron wire
1 box glazier points
Enamel: red, green, and black

The electromagnetic model I, as shown in Fig. 1, Plate XIV and Plate XV, was designed to show the magnetic lines of force built up about a single straight conductor carrying an electric current. It consisted of a straight piece of number four galvanized iron wire mounted horizontally with an arrow made as shown in Fig. 1, Plate I, soldered to each end.

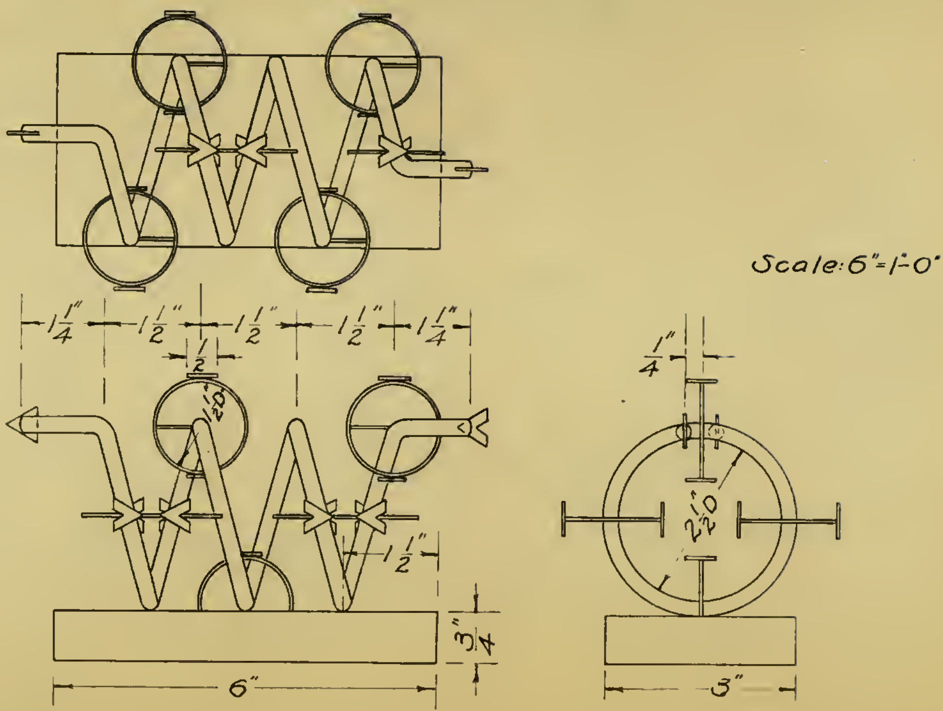
current. Large circles of number sixteen galvanized iron wire were mounted around the conductor and perpendicular to it. These circles had arrows soldered to them that indicated the direction of the magnetic lines of force. The model showed the relationship in position and direction of the magnetic field caused by the electric current flowing through a conductor.

Electromagnetic model II of the group is illustrated in Fig. 2, Plate XIV and Plate XVI. This is a model of a solenoid. A wire representing the conductor was wound into a helix with each end extended horizontally. This helix was made of number four galvanized iron wire. Arrows were soldered to the extended ends to indicate the direction of the current. This helix was mounted upon the wooden base by a small strip of wood held into place by means of screws. The large circles representing the flux were mounted in the same manner as in the first model. This model was designed to show the simple magnetic field around each turn of the conductor in the solenoid. The conception of all the lines of force on the outside of the solenoid going in one direction and all lines of force on the inside going in the opposite direction was excellently shown with this model.

EXPLANATION OF PLATE XVI

Working drawing for the electromagnetic model No. II.

PLATE XVI



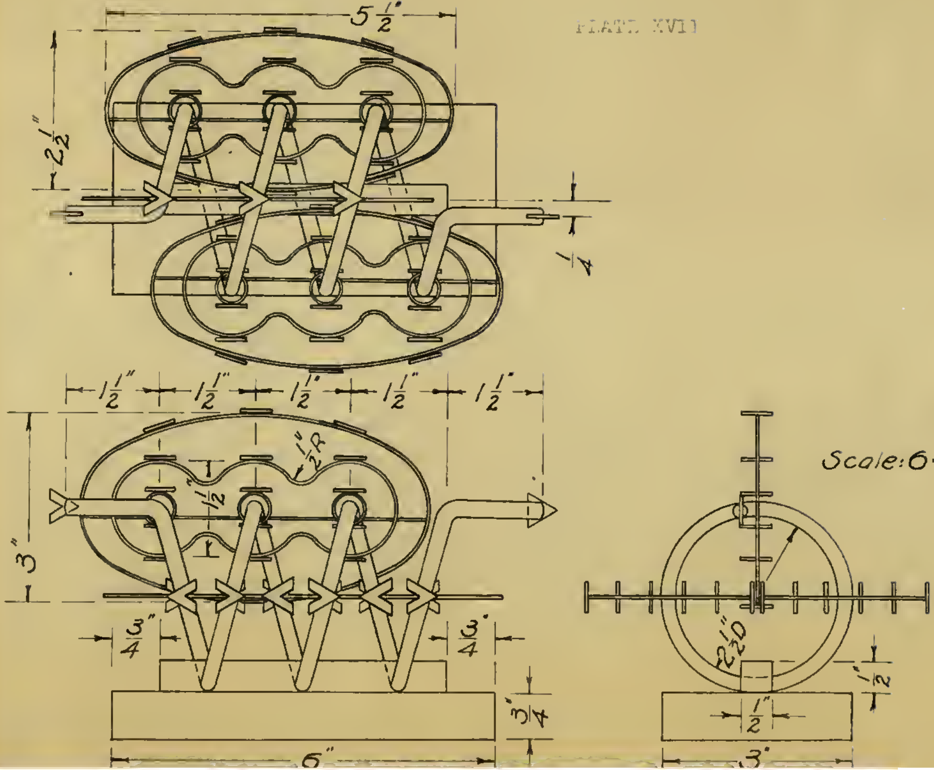
Electromagnet model III of the group is illustrated in Fig. 3, Plate XIV and Plate XVII. It was similar to the second model. The principal difference between the two was that the third one showed the composite field built up around the solenoid. The individual lines were represented by small circles mounted closely about the conductor and larger semicircular wires were mounted concentric to the smaller circles. The latter were connected in a series arrangement to represent the evolution of a continuous line of force. A third outside loop of wire showed the resulting line of force that passed through the solenoid and returned on the outside forming a continuous line of force. This made an excellent device for showing the relation between Oersted's discovery and Henry's electromagnet.

Electromagnetic model IV is illustrated in Fig. 4, Plate XIV and Plate XVIII. This model showed a loop of the conductor placed in a magnetic field. The model was arranged so that it could be used to represent the conductor moving in the magnetic field and causing a current to be induced in the conductor. It was also used to show that a current flowing through the conductor will be forced out of the magnetic field. The model showed the individual lines of force caused by the current in the conductor and

EXPLANATION OF PLATE XVII

Working drawing of the electromagnetic model No. III.

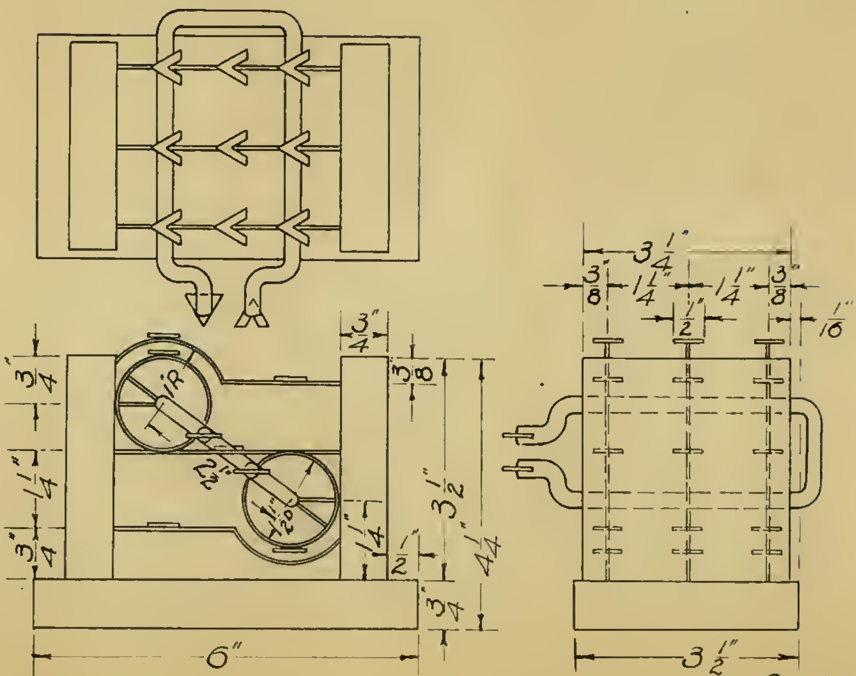
PLATE XVII



Scale: 6" = 1'-0"

EXPLANATION OF PLATE XVIII

Working drawing for the electromagnetic model No. IV.


3/4"
3/4"
1 1/4"
3/4"
1R
1
2 1/2"
1 1/2" D
3/8"
1 1/4"
1/2"
3 1/2"
4 1/4"
3/4"
6"
3 1/4"
3/8"
1 1/4"
1 1/4"
3/8"
1/2"
1/16"
3 1/2"

Scale: 6"=1-0"

also the distortion produced in the magnetic field of the apparatus. It can be seen readily that both the generator and motor affects as well as many other characteristics could be shown by this piece of equipment.

This group of models, being made of the same kinds of material, using the same color scheme, and progressing from the simple ideas to the more complex ones, make a set which was very useful in the study of electricity and magnetism. These models were very effective in building up the conceptions one by one and carrying the last idea into the next. They were also employed successfully as a means of review and as a summary of the work after the unit had been completed. They were used as a means of transferring the scientific principle to the practical application that was to be studied.

THE ELECTROMAGNET

The electromagnet is an essential part of many electrical machines. The project shown in Fig. 3, Plate XX, is a convenient type. It gave good results on low voltage direct current electricity and was suitable for use in making demonstrations.

EXPLANATION OF PLATE XIX

Fig. 1. A combination compass and dip needle.

Fig. 2. A demonstration electric motor.

Fig. 3. A home made spectroscope.

Fig. 4. A double convex lens model.

PLATE XIX

Fig. 1

Fig. 2

Fig. 3

Fig. 4

EXPLANATION OF PLATE XX

Fig. 1. Working drawing for the jumping ring.

Fig. 2. Attachment for the jumping ring apparatus.

Fig. 3. Working drawing of a simple electromagnet.

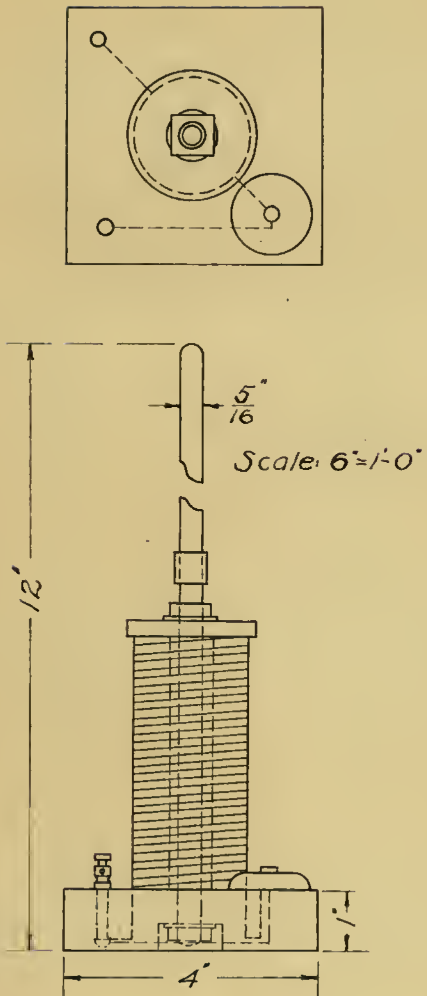


Fig. 1

Fig. 2

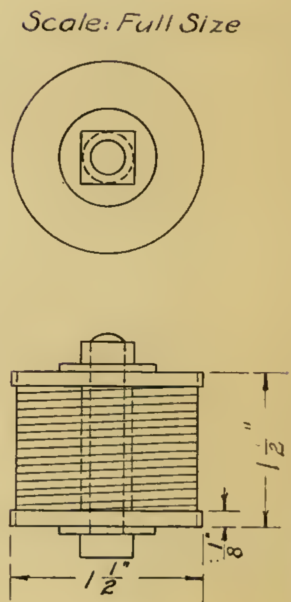


Fig. 3

List of Materials

1 machine bolt	1/4" x 1 1/2"
1 thin wall iron pipe	5/16"x 2"
2 washers	1/2"
2 fiber discs	1 1/2" diameter
No. 24 D.C.C. copper wire	

One washer and one fiber disc were placed on the bolt. Then, the iron pipe was placed on the bolt and this was followed by the other fiber disc, iron washer, and the nut. The washer and fiber discs were held firmly in place when the nut was tightened. This made the form upon which the coil for the magnet was wound. The insulated wire was wound on this form until it was within one-eighth inch from the outer edge of the disc. The loose end was fastened by putting it through a small hole drilled through the edge of the fiber disc. This made a good problem in the study of elementary electricity.

THE JUMPING RING

This project is one that is useful in demonstrating induction and is interesting to manipulate. Figure 1, Plate XX, shows the working drawing for this apparatus. It was designed as a follow-up project for the electromagnet.

List of Materials

1 hardwood board	1"	x 4"	x 4"
1 thin wall iron pipe	3/8"	x 4"	
1 aluminum ring	1/2"	x 3/4"	
1 iron rod threaded 5" from one end	5/16"	x 12"	

1 fiber disc 2" diameter and 5/16" hole at center
1 push button
2 binding posts
1 pound of annunciator wire

One nut was screwed to the end of the threads on the iron rod. Then the washer, fiber disc, iron pipe, baseboard, washer and nut were placed on the rod in the order mentioned. These parts made a rigid form to receive the wire when the nut was tightened. The coil was wound with one pound of number eighteen annunciator wire. This coil was connected in series with the binding posts and push button. When the apparatus was connected with a 110 volt A.C. circuit and the push button pressed, the aluminum ring jumped off the end of the iron rod. A second demonstration with this apparatus was done by taking the coil of wire soldered to a flashlight bulb, shown in Fig. 2, Plate XX, and placing it over the iron rod.

AN ELECTROSCOPE

Electricity has always been fascinating because of its resemblance to magic. A device, which was constructed in a short time, that could detect small charges of electricity and show some of their characteristics, made an interesting problem. Figure 1, Plate XXI, shows an electroscope built in a flat bottom flask as used in the chemistry laboratory, although almost any glass bottle could be used.

List of Materials

1 medium size bottle with stopper	
2 pieces of tinfoil	1/4" x 1"
1 metal rod	1/4" x 3"
1 large ball bearing	

The ball bearing was soldered to one end of the metal rod and the other end was slightly flattened. The two pieces of tinfoil were glued to the flattened portions of the metal rod after it had been inserted in the stopper of the glass bottle. When these parts were assembled the stopper was carefully replaced in the glass bottle. Some of the boys made this project for their home laboratory.

EXPLANATION OF PLATE XXI

Fig. 1. Working plan for an electroscope.

Fig. 2. Working plan for a Leyden jar.

Scale: Full Size

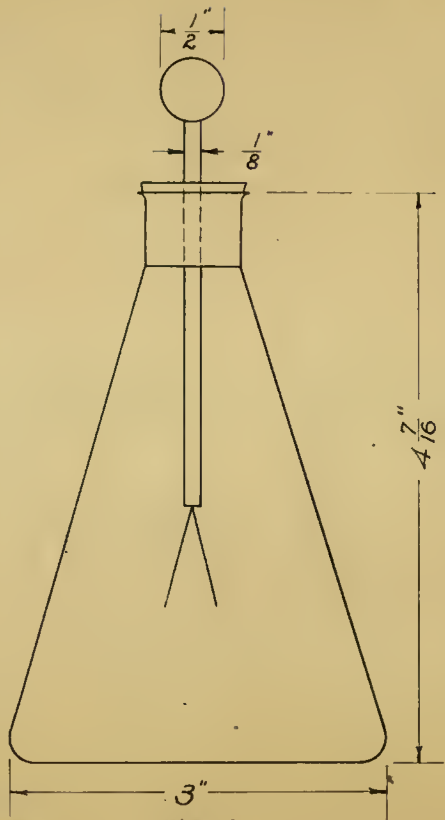


Fig. 1

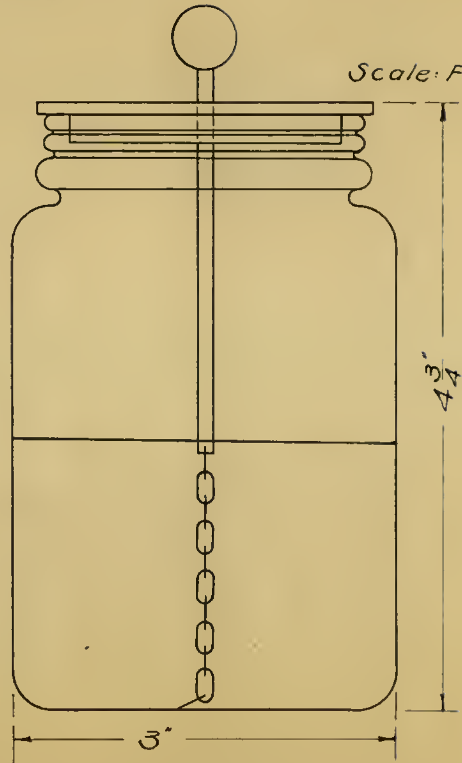


Fig. 2

A LEYDEN JAR

The electrical charges built up by friction are small and better results for demonstrations or for home experiments can be obtained by use of the Leyden jar which accumulates the charges. The Leyden jar (Plate XXI, Fig. 2), was made from a pint fruit jar, although any wide mouth glass jar would serve the purpose.

List of Materials

1 block of wood	3/4" x 3" x3"
1 small chain	3"
1 metal rod	1/4" x 3"
1 large ball bearing	
1 piece tinfoil	App. 1/2 sq. ft.

The piece of wood was turned out to serve as a lid for the Leyden jar. The ball bearing was soldered to one end of the metal rod. Then the rod was inserted in a small hole in the center of the lid. The chain was attached to the other end of the rod by a loop of wire through the end link soldered to the end of the rod. The lower half of both the inside and outside of the jar were lined with tinfoil pasted to the glass. When the parts were all assembled and the lid put in place, the jar was ready to be charged.

A TIME CONTROL FOR AN ELECTRIC CIRCUIT

The design of this project was the result of a request for a device that would automatically turn off the lights in a poultry house at any desired time. This project was made so that it could be used to turn the current off, could turn it on, or could turn one current on and another off at the same time (Plate XXII). The construction did not impair the alarm clock's usefulness or appearance.

List of Materials

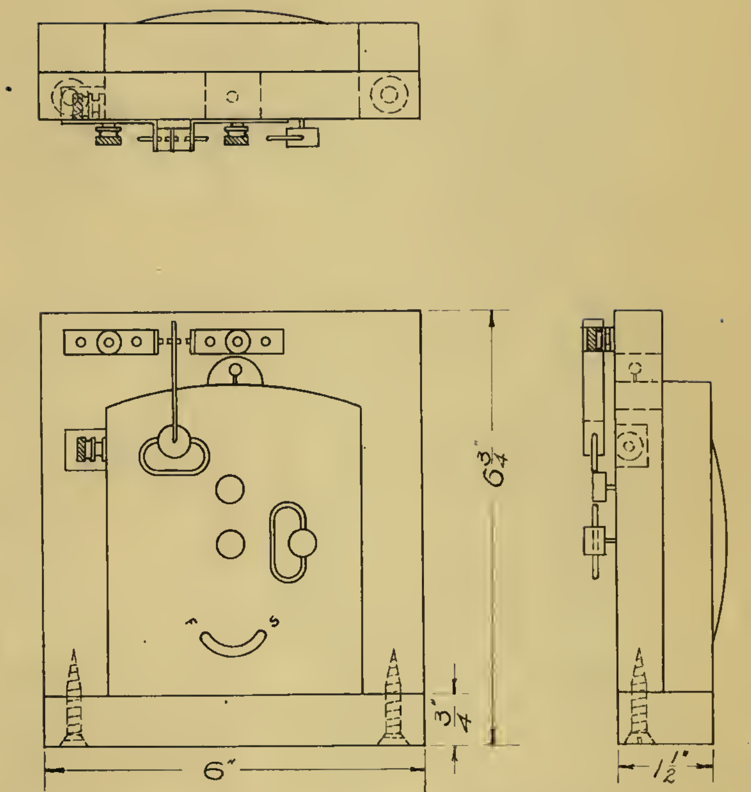
1 walnut board	3/4" x 1 1/2" x 6"
1 walnut board	3/4" x 6" x 6"
2 No. 9 F.H. 1 1/2" wood screws	
1 clock spring	1/4" x 2"
4 platinum points	
3 binding posts	
1 alarm clock	
2 brass corner braces	
4 No. 8 R.H. 3/4" wood screws	

The base board was cut to the size of the bottom of the clock plus one and one half inches. The square board was cut out so that the clock fitted inside of it. The clock was held in place by tacks through from the inside of the case. One binding post was attached to the side of the clock case. The piece of clock spring was soldered to the alarm key. The other end had platinum points

EXPLANATION OF PLATE XXII

Working drawings for a control for an electric circuit.

PLATE VIII



Scale: 6"=1'-0"

soldered to it directly opposite each other. One arm of each brass corner brace was cut to one half inch and mounted to the board directly above the alarm key with one half inch gap between them. A platinum point was soldered to each so that it was in line with the points of the arm from the alarm key. A binding post was soldered to each brass corner brace. The alarm was turned until the contact points were touching, and the alarm was set for the desired time. When the alarm went off the alarm key turned, causing one set of points to break contact and the other set to make contact. This simple project was as reliable as the alarm clock.

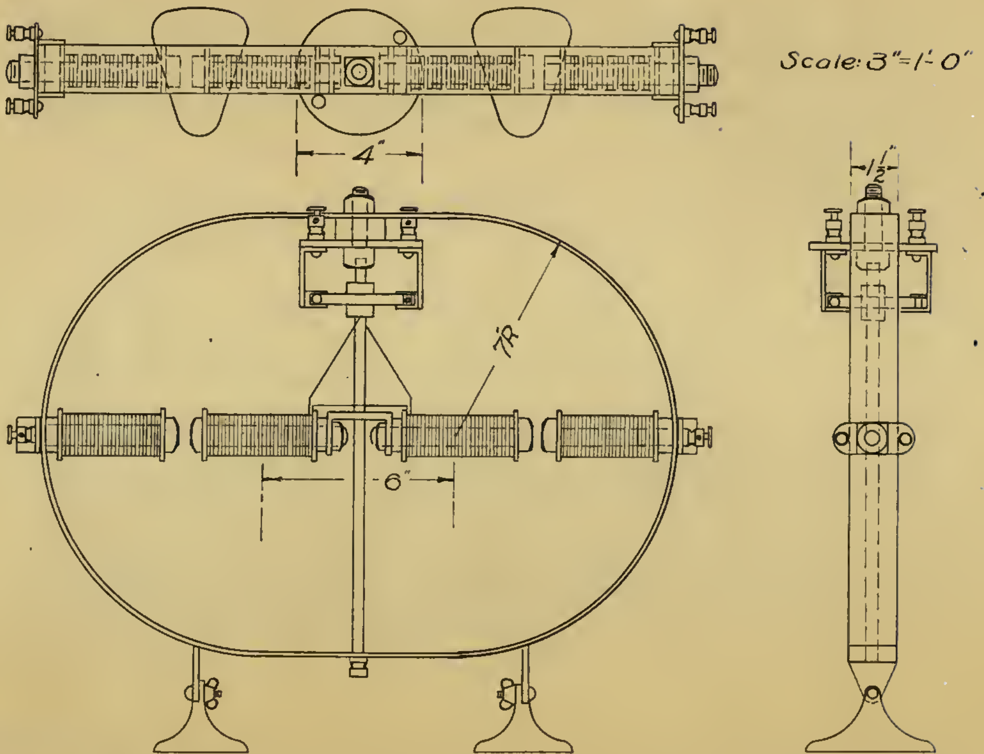
AN ELECTRIC MOTOR

This electric motor was designed for a class project. It was built by students as a laboratory exercise. It was built at minimum expense and was a valuable addition to the school laboratory. The motor is illustrated in Fig. 2, Plate XIX, and a working drawing is shown in Plate XXIII.

EXPLANATION OF PLATE XXIII

Working drawing for an electric demonstration motor.

PLATE XXIII



List of Materials

1 iron frame made of		1/8" x 1 1/2" strap iron
1 bracket	1"	x 1 1/2" x 2"
2 stove bolts		1/2" x 1"
2 machine bolts		1/2" x 4"
2 machine bolts		1/2" x 5"
1 machine bolt		1/2" x 2"
1 brass tube		3/4" x 1"
1 iron rod		1/4" x12 1/2"
2 oval fiber discs	1	1/2" x 3"
2 small bolts		1/8" x 1/2"
2 corner braces		1/4"
8 nuts		1/2"
8 washers		1/2"
2 wing nuts		1/2"
2 bases from discarded fans		
6 binding posts		
1 circular fiber disc 4" diameter		
1 foot brass spring wire		
1 pound bell wire		
1 battery nut		
1 small ball bearing		

The iron frame was made by a local blacksmith. One half inch holes were drilled at the center of the top end at the center of the two ends. A one fourth inch hole was drilled at the center of the bottom. The battery nut was soldered on the bottom of this hole and filled with solder. Then, it was reamed out to receive a small ball bearing which acted as an end bearing for the shaft. The top bearing was made of a one half inch steel bolt as shown in Fig. 7, Plate I.

The electromagnets for the field coils and for the armature were made by placing two washers on the bolt and screwing the nut on as far as it would go. The space between the washers was wound with four layers of bell wire. A bracket was made from a four inch piece of the frame material bent at right angles one inch from each end, with a one half inch hole through each side and a one fourth inch hole through the center. The armature was assembled by placing the threaded ends of the bolts of the armature coils through the holes in the brackets. Those were held in place by lock nuts. The bracket was mounted on the shaft and soldered in position.

The field coils were mounted to the frame through the end holes and were held by lock nuts. The fiber oval pieces had a binding post mounted near each end and a one half inch hole was drilled in the center of each. This unit was mounted on the frame by passing the bolt of the field magnet through the center hole. This was held in place by the lock nut. The ends of the lead wires from the field coils were attached to the binding posts which served as terminals.

The circular fiber disc that was used as an adjustment for the brushes had a one half inch hole drilled through the center and two binding posts were mounted opposite

each other near the edge of the disc. This disc was mounted between the head of the upper bearing bolt and the inside of the frame. The brush holders were made from the brass corner braces that had been bent to shape. These were mounted by the screws that held the binding posts in place. The brushes were made from a loop of brass spring wire and were mounted to the brush holders by two small bolts.

The commutator was made by turning a piece of wood to fit snugly into the brass tube. A hole was drilled through the center of the wood along the axis of the commutator. The brass tube was sawed lengthwise on opposite sides which formed the two segments of the commutator. These two segments were held in place by small wood screws at each end of the segments. The leads from the armature coils, which were connected in series, were soldered so that one lead went to each segment.

The separate terminals made it possible for the motor to be connected in series or parallel. The motor was operated on a six volt D.C. circuit and also on a twelve volt A.C. circuit.

A CRYSTAL RADIO RECEIVER

The crystal radio receiver is limited in its range of reception because it depends entirely upon the energy from the broadcasting station for its operation. The radio shown in Fig. 1, Plate XXIV, which was built by students, has picked up several distant stations.

List of Materials

1 large cigar box
1 cylindrical ice cream carton
5 binding posts
1 spool
5 large brass paper fasteners
1 galena crystal
60 feet of No. 24 magnet wire
1 stove bolt 1/4" x 2"
2 small bolts 1/8" x 3/4"
1 strip of tin 1/2" by 1 1/2"
1 coiled spring 3/8" x 1"
1 strip spring metal 3/8" x 2"
2 nuts 1/4"

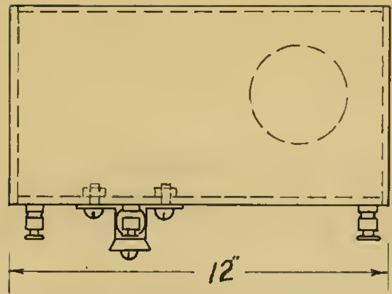
The switch was built on the front of the box. The contact points were made of brass paper fasteners and the knob was made from half a spool. This knob and the contact arm were fastened together by a stove bolt and a nut. This bolt was extended through a hole in the box and a washer, the coiled spring, another washed, and the nut were placed on the bolt on the inside of the box.

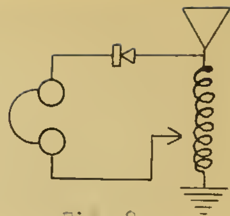
EXPLANATION OF PLATE XXIV

Fig. 1. Working drawing for a crystal radio receiver.

Fig. 2. Wiring diagram for the crystal radio receiver.

Fig. 3. Working drawing for a telegram sounder.





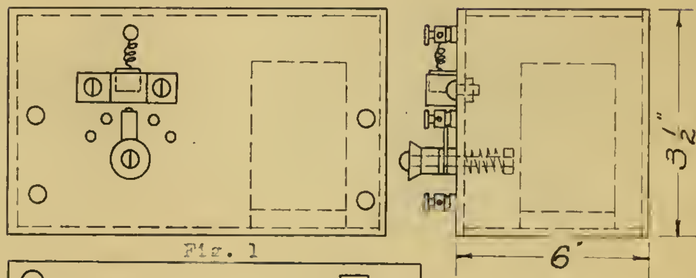
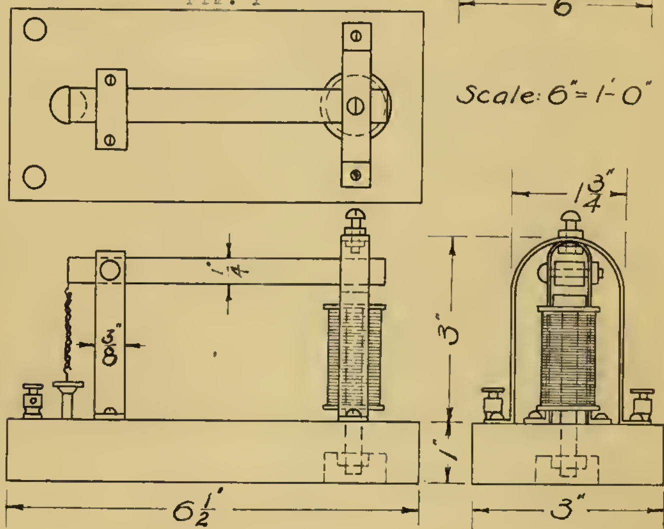


Fig. 1



Scale: 6" = 1'-0"

Fig. 3

The crystal was mounted behind a small strip of tin that was mounted on the front panel just above the switch. A binding post was mounted above the crystal to hold the cat whisker. Two binding posts were placed at the left end of the panel for the head phones and two at the right for the atenna and ground connections. The inductance coil was wrapped around the ice cream container. A coil of sixty turns was made with taps for soldering leads made at each ten turns beginning with the twentieth turn. Each one of these taps, including the last end of the coil, were connected and soldered to the contacts of the switch in consecutive order. Then the parts were wired up as shown in Fig. 2, Plate XXIV

A TELEGRAPH SOUNDER AND KEY

The telegraph sounder and key are standard laboratory equipment. Working plans for this kind of a project are in demand almost every year. The sounder and key were made separately so that the key could be used as a push button. The working drawings of the sounder are shown in Fig. 3, Plate XXIV, and those for the key in Fig. 3, Plate XXVIII.

List of Materials

1 hardwood board	1"	x 3"	x 6 1/2"
1 hardwood board	3/8"	x 2"	x 4"
1 brass strip	1/16"	x 3/8"	x 8 1/2"
1 brass strip	1/16"	x 3/8"	x 6"
1 brass strip	1/16"	x 3/8"	x 3"
1 machine bolt	1/4"	x 2 1/2"	
4 stove bolts	3/16"	x 3/4"	

4 No. 8 R.H. 3/4" wood screws
1 No. 9 F.H. 1 1/2" wood screws
2 1" fiber washers
No. 26 magnet wire
4 binding posts
1 rubber band
1 square iron bar from door latch
1 spool

The sounder was built on the large board. The magnet coil was wound on the machine bolt between the two fiber washers and was mounted on the base by a lock nut counter sunk in the base. The long brass strip was bent into an arch shaped form and was fastened to the base in a position over the magnet. A stove bolt with a lock nut was inserted in a hole at the top of the frame for a spacing adjustment. The sounder bar was made from an iron bar taken from a door lock. The six inch brass strip was bent to make the support for the sounder bar. It was placed in such a way that the inside hole of the bar was used for the pivot bolt. A washer soldered to the top of a flat head wood

screw, as shown in Fig. 2, Plate I, was used as a tension adjustment for the sounder bar. A hook was soldered to the top of the washer which was connected by a rubber band to a hook soldered to the end of the sounder bar. The binding posts were mounted on one end of the base and connected under the base to the magnet.

The key was mounted on the small block of wood. The three inch brass strip was bent to shape and a half spool was bolted to one end to form the knob. The other end was bolted to the base. A stove bolt that was used as a connection was set in the base directly below the spool. Two binding posts were mounted on one end of the base and one was connected to the lower contact point. The other was connected to the bolt that held the contact arm in place.

AN AUTOMATIC ELECTRIC BASKETBALL CLOCK

The basketball clock is a difficult project which requires considerable skill in making the detailed parts and in following wiring diagrams. The usefulness of the finished product and the publicity that it receives makes it an undertaking that will appeal to advanced students. This clock was constructed through the cooperation of the

EXPLANATION OF PLATE XXV

Fig. 1. Front view of the automatic electric basketball clock.

Fig. 2. Back view of the automatic electric basketball clock.

PLATE XXV

Fig. 1

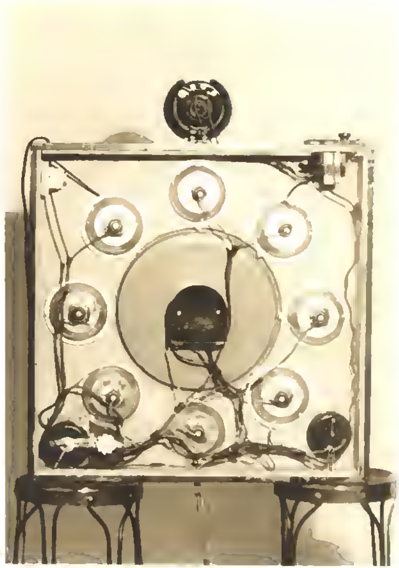
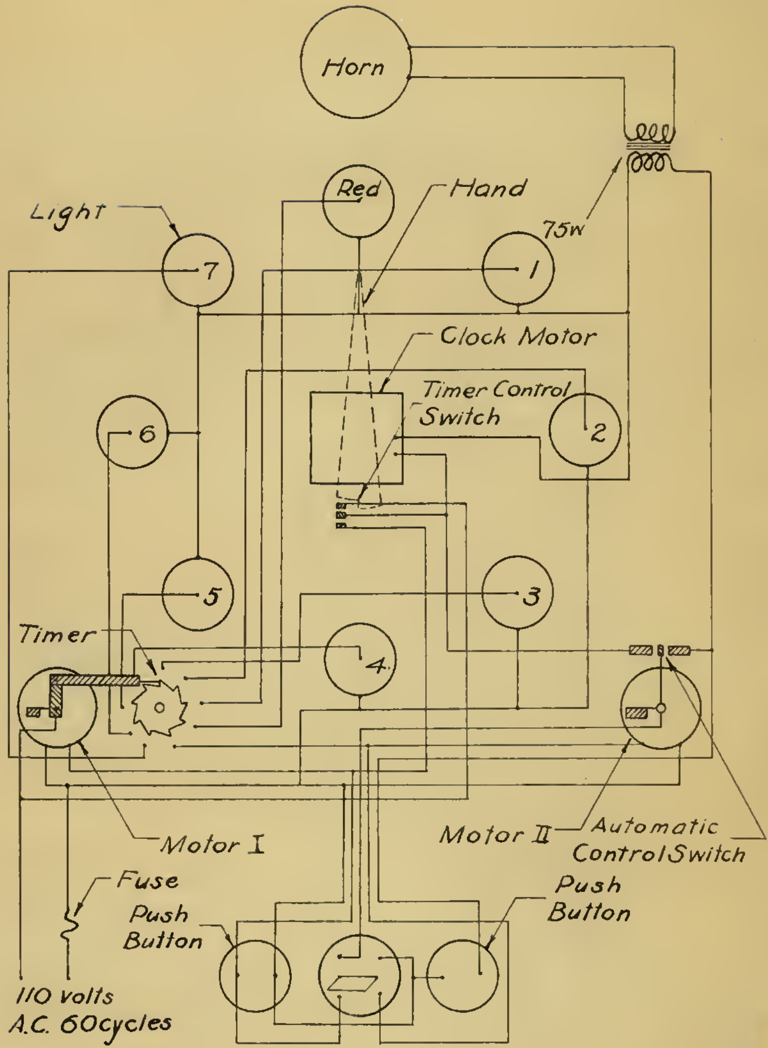


Fig. 2

physics class and the school shop. It was used for all the junior and senior high school games and gave trouble-free service throughout the season. The clock automatically changed the lights, stopped itself, and sounded the signal at the end of the quarter. The controls at the timekeeper's table enabled him to start or stop the clock, reset the numbers on the dial, and sound the signal. The face of the clock was arranged to show the exact number of minutes and seconds left in each quarter. The changing illuminated numbers gave the clock an attraction not found in most commercial clocks. A picture of the clock is shown in Plate XXV, a wiring diagram in Plate XXVI, and the details for the unit parts in Plate XXVII.

EXPLANATION OF PLATE XXVI

Wiring diagram of the automatic electric basketball clock.



Horn
75w
Red
Hand
Light
7
1
Clock Motor
Timer Control
Switch
6
2
5
3
Timer
4
Motor I
Motor II
Automatic
Control Switch
Fuse
Push
Button
Push
Button
110 volts
A.C. 60 cycles

EXPLANATION OF PLATE XXVII

Fig. 1. Detail of the timer unit for the basketball clock.

Fig. 2. Detail of the automatic control for the clock.

Fig. 3. Detail of the front panel of the clock.

Fig. 4. Detail of the timer control switch for the clock.

Fig. 5. Diagram for making a reflector for the clock.

Fig. 6. Sectional detail of an illuminated number of the clock.

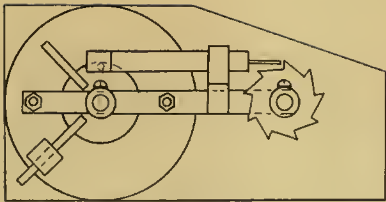
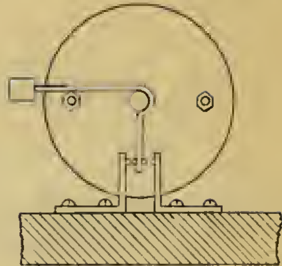


Fig. 1



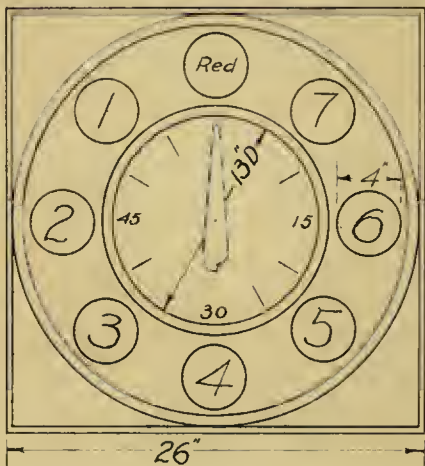


Fig. 3

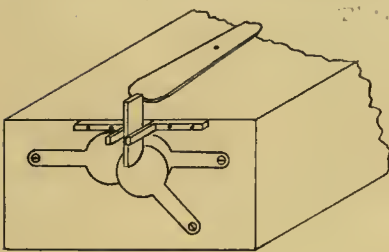
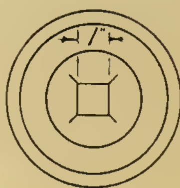
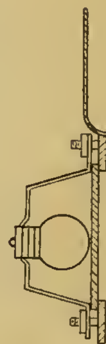


Fig. 4





List of Materials

4 pine boards	3/4" x 4" x 26"
2 plywood panels	1/4" x25 1/4" x 25 1/4"
8 frosted glass plates	4 1/2" x 4 1/2"
1 strip brass	1/16" x 3/8" x 24"
1 piece of 28 gauge tin	2" x 12"
1 walnut board	3/4" x 3" x 8"
1 plywood board	1/4" x 4" x 6"
1 piece celluloid	1/4" x 1/2" x 2"
16 stove bolts R.H.	1/4" x 3/4"
9 brass bolts with hexagonal nuts	3/16" x 3/8"
1 rod	3/16" x 3"
1 serving tray	13" diameter
1 No. 9 wire	12"
8 individual pie tins	
8 7 1/2 watt, 110 volt light bulbs	
1 self starting electric clock	
2 small electric fans	
1 75 watt transformer	
1 auto horn	
1 porcelain socket with fuse	
3 pair model T breaker points	
2 push buttons	
1 three way toggle switch	
1 small brass safety pins	
rubber insulated wire	
enamel, black construction paper, and miscellaneous screws for mounting parts.	

The clock was built from the four, twenty-six inch pine boards. The corners were joined by end lap joints held together by wood screws. The front and back were rabbited to receive the front and back panels in such a way that they were flush with the frame. The openings for the lights and the center dial were cut in the front

panel. The holes were drilled for mounting the reflectors and the center dial. The reflectors were made from individual pie tins. A one inch square hole, with the corners cut back at forty-five degree angles, was cut in the center of the bottom of each pie tin (Plate XXVII, Fig. 5). The light bulbs were screwed into these holes and soldered. The lenses for the lights were made from frosted glass plates, four and one half inches square. The numbers were made by tracing around house numerals on black construction paper and were glued to the front of the lenses. The face, hands, and gears for the hour and minute hands were removed from the electric clock. The face was used as a template to mark the holes on the serving tray for mounting it on the clock. Then the clockworks including the case were mounted to the serving tray which took the place of the face of the clock. The assembled lights and the assembled center dial were mounted on the back of the front panel (Plate XXVII, Fig. 6).

The remainder of the clock consisted of units which were built and installed separately. The first unit was called the timer. Its detail is shown in Fig. 1, Plate XXVII. The unit was built on a three inch by six inch plywood board that had one corner out so that it would fit in one corner of the case. An electric motor which

will be referred to as motor No. I was centered on the large end of the board by means of the bolts that held the motor frame together. A five inch piece of brass was drilled near one end to fit the motor frame bolts. Another hole was drilled to let the shaft of the motor through. Then a hole was drilled at the other end of the brass strip to form a bearing for the ratchet wheel. The other bearing for the ratchet shaft was drilled in the plywood back. The nine-sprocket ratchet wheel and the crank arm on the motor shaft were made from the hubs of the electric fans. The distributor of the timer was made by evenly spacing nine brass bolts around a circle on the plywood back and centered about the bearing for the ratchet shaft. The hexagonal nuts, being arranged closely together, served as the contact points for the timer. Wires were soldered to the heads of these bolts which served as leads to the lights and to the automatic stop switch. A brass strip, loosely rivited to the crank on the motor shaft, served as a push rod to operate the ratchet wheel. An arm with weight attached was used to return the motor shaft to its original position after operating the ratchet. This weighed arm and the other arm shown in the drawing served as stops to control the length of the stroke of the crank. A small brass safety pin was soldered to the back of the ratchet

wheel and bent into a position such that it served as a contact arm for the timer. The ratchet was adjusted so that this contact pin would stop on the center of each point every time the motor tripped it. Every time the motor was turned on, the ratchet turned one-ninth of a revolution and the timer moved up on contact point. Eight contact leads were connected to the lights in consecutive order from seven to zero. The ninth contact was connected to motor No. II. The current came into the timer through its frame and left through the contact arm to the lights. This unit was installed in the lower left corner of the case.

A second unit referred to as the automatic control unit is shown in Fig. 2, Plate XXVII. It consisted of a motor mounted on the front panel with a contact arm and a weighted arm soldered at right angles to each other on the shaft. Two brass arms were mounted in the bottom of the case so they were one half inch apart and the gap was just below the shaft of motor No. II. The contact arm from the motor was suspended between these brass strips. Platinum points were soldered to the upright pieces and to the contact arm from the motor so they would make good electrical connections. The current was connected to the frame of the motor so that a circuit was completed with

whichever side the contact arm was touching. This unit was installed in the lower right corner of the case.

Another unit, called the timer control unit, was built on the bottom of the electric clock case (Plate XXVII, Fig. 4). The switch consisted of three contact springs made from model T breaker points. This formed a two circuit switch. It was so arranged that one circuit was turned on before and turned off after the contact was made for the other circuit. This made it impossible for the clock to be turned off while motor No. I was on contact, since the first part of the switch controlled the clock independently of the other switches. The springs were mounted so that the contact points were all separated. When the second hand of the clock was in the proper position, it pressed down on a short celluloid lever which in turn pressed upon the contact springs. This closed the two circuits and then released them an instant later.

The signal system consisted of a 75 watt transformer and an auto horn. The transformer was mounted in the upper right inside corner of the case and the auto horn was installed on top of the case in the center.

When all units were installed, the clock was ready to wire electrically. The wiring diagram was studied carefully so as to make the wiring as neat and compact as

possible. Rubber insulated wire was used throughout. The simplified wiring diagram is shown in Plate XXVI. The switch board which was used on the timekeeper's table was built on a walnut board. It consisted of two push buttons and one three way toggle switch. The three way switch was taken apart and the link between the common terminals was removed. This made a double-throw type of swithh. When the quarter ended, the clock circuit was broken and the horn circuit closed. The horn continued to sound until the toggle switch was turned off by the timekeeper. When the toggle switch was off it connected the motor No. I to the same circuit as motor No. II. Then motor No. I operated and turned the ratchet wheel which disconnected the current from the two motors. This caused the horn to stop and the clock circuit to close, but since the clock circuit was turned off at the timekeeper's switch, the clock would not run until it was turned on again. The clock was reset by pressing the push button connected to motor No. I. The horn sounded when the push button connected to the transformer was pressed. A five wire cable was used to connect the clock to the timekeeper's table.

The practical value of this project has been well established. The clock has been used to keep official time in district basket ball tournaments, and several re-

quests have been made for plans for the building of the clock as a school project.

AN ILLUMINATED SIGN

The illuminated sign was a project which was useful and popular. Figure 1, Plate XXVIII shows the sign set up for a house numeral, but it can also be used for club signs, commercial signs, church signs, etc.

List of Materials

2 pine boards	1" x 5" x 15"
2 pine boards	1" x 5" x 7"
1 frosted glass	7" x14"
1 transparent glass	7" x14"
2 porcelain sockets	
2 case bulbs	
1 plywood panel	7" x14"
8 No. 8, F.H. 1 1/2" wood screws	
4 No. 8, R.H. 1 1/2" wood screws	

The case for the sign was built first. Grooves were cut inside the top, bottom, and ends to receive the transparent glass, the frosted glass, and the back panel as shown in Fig. 1, Plate XXVIII. Porcelain sockets, which were used for the case bulbs, were mounted at the center on the inside of the ends of the case. The numerals on the front glass were painted on with opaque paint.

The sign may be made more elaborate by using vacuum or gas filled tubes operated by an induction coil. The

EXPLANATION OF PLATE XXVIII

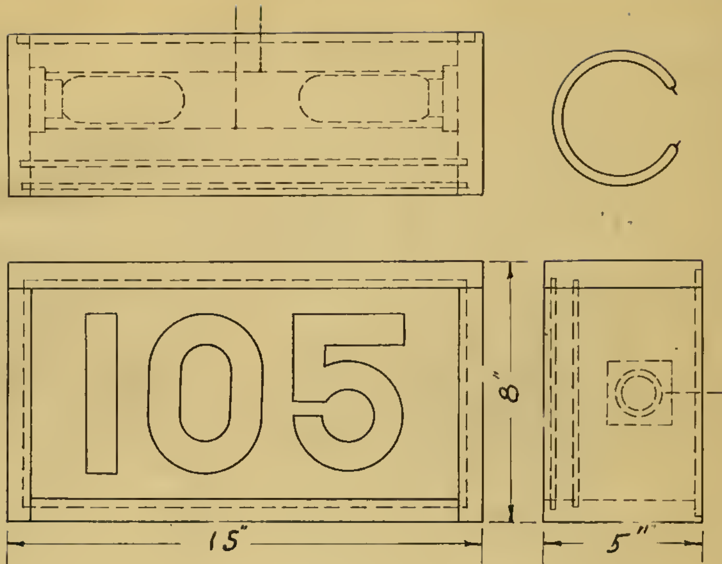
Fig. 1. Working drawing for an illuminated sign.

Fig. 2. A Geissler tube.

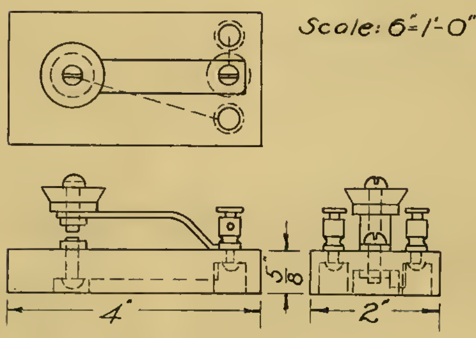
Fig. 3. Working drawing for a telegraph key.

Fig. 4. Working drawing for a whistle.

Fig. 5. Diagram of the chimes.



ıg. 1



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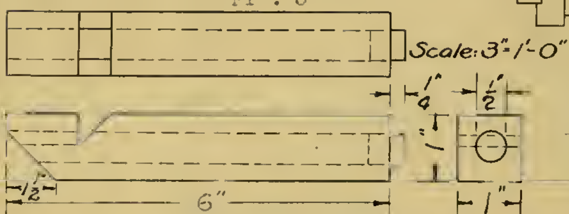
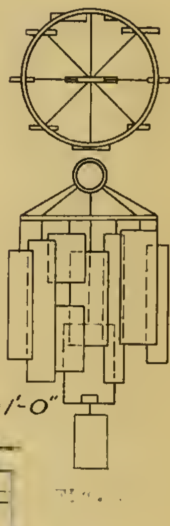




gas tubes were made by shaping a piece of glass tubing, evacuating, and sealing platinum wire through each end as shown in Fig. 2, Plate XXVIII. Different colors can be produced by using different gases in the tube before it is evacuated. Air gives a violet color, hydrogen a red color, and mercury vapor a blue color. Changing color effects can be produced by taking three flash buttons that are used with red, blue, and yellow light bulbs, grouped behind a frosted glass. There are seven possible combinations since the flash buttons will flash at different time intervals.

A WHISTLE

An interesting number for an assembly program can be built around the use of whistles. If whistles are made with varying lengths they can be tuned to a musical scale by adjusting the plugs at the ends. When the program is over the whistles make a good kit for use in the study of sound in the physics class.

List of Materials

1 maple block	1" x 1" x 6"
1 dowel rod	1/2"x 2"

Figure 4, Plate XXVIII shows how the whistle was made. A hole was made through the piece of wood before the notches were made. One piece of dowel rod was used for the end plug and another for the half-plug in the mouth piece.

CHIMES

A set of chimes that make musical sounds gives a cheerful atmosphere to a sunroom, flower garden, or verands. This problem appealed to the girls who wanted to make a project for their home.

List of Materials

1 small metal ring
1 wire ring 2 1/2" diameter
3 feet small fishing line
Miscellaneous glass plates

The chimes consisted of a group of glass plates cut in varying lengths and widths supported by fish line glued to the ends of the plates. These strings were tied to the small metal ring in such a way that they were able to move about freely. One plate was supported by a string from the center of the circle and a cardboard was hung from its lower end so a breeze would cause it to swing about in the breeze and strike the other plates as they moved in the

wind. A diagram of this project is shown in Fig. 5, Plate XXVIII.

A PERISCOPE

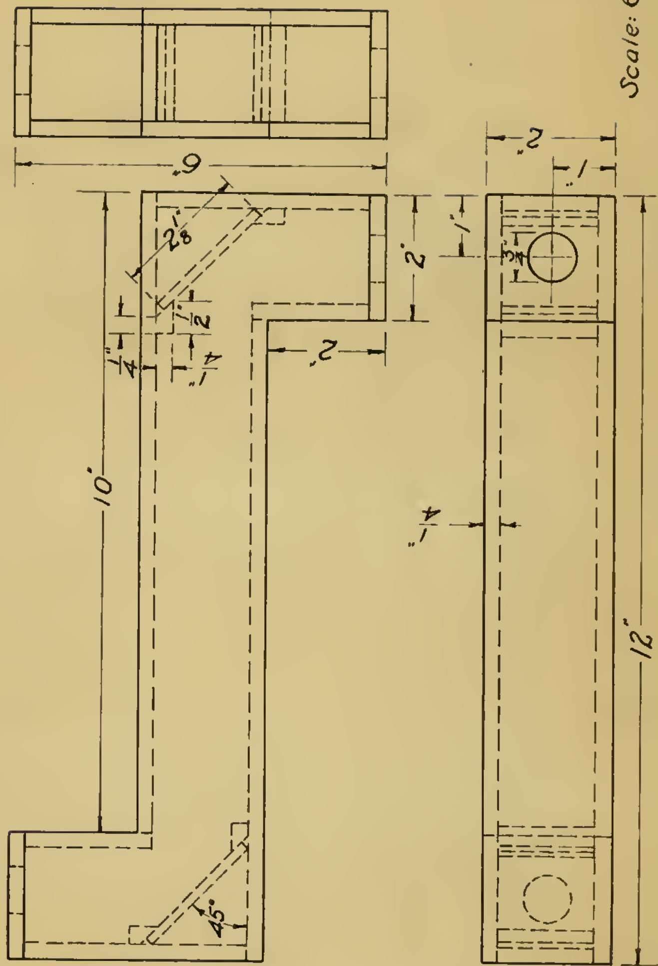
The periscope is a good problem in reflection and is interesting because it enables one to see around corners. The drawing in Plate XXIX, gives details for making a simple periscope that is large enough to be practical and yet small enough to be stored as permanent laboratory equipment. If the student wants to build one of different size, he can vary the length and still use the structural details of the drawing. An interesting variation of this problem is to make the upper arm of the periscope turn back in the same direction as the lower arm. If two periscopes are used together they may be arranged so that the observer apparently sees through an intervening opaque medium.

List of Materials

2 plywood boards	1/4" x 5 1/2" x 12"
2 plywood boards	1/4" x 2" x 10"
4 plywood boards	1/4" x 2" x 2"
2 pine strips	1/2" x 1/2" x 1 1/2"
2 mirrors	2 1/8" x 1 1/2"
Brads and glue	

EXPLANATION OF PLATE XXIX

Working drawing for the periscope



Scale: 6" = 1'-0"

PLATE XIX

The parts were assembled as shown in Plate XXIX. One face was left open until the mirrors were mounted. When the project was completed, it was given a coat of dark oak oil stain for a finish.

A STROBOSCOPE

What makes the wheels in moving pictures appear to run backwards as well as forward? This question is invariably asked when studying the motion picture machine. The stroboscope gives the answer in a very interesting manner.

List of Materials

2 pieces of white cardboard 12" diameter
1 electric fan
1 hand rotor wheel

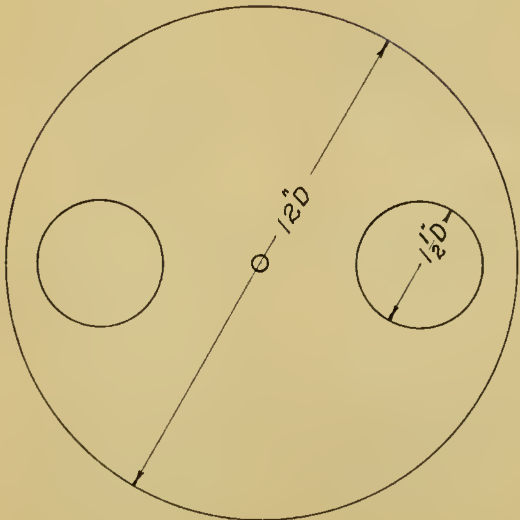
Two twelve-inch discs were cut from white cardboard. One disc was laid out according to the design in Fig. 2, Plate XXX. The other disc was cut out as shown in Fig. 1, Plate XXX. The pattern of the disc shown in Fig. 2, was colored with bright, contrasting colors. All corresponding parts were made the same color. The rim and spokes of the wheel were colored black.

The guard was removed from the electric fan and the colored disc was mounted on the fan blade. Strips of the

EXPLANATION OF PLATE XXX

Fig. 1. The shutter disc for the stroboscope.

Fig. 2. The pattern disc for the stroboscope.



Scale: 4" = 1'-0"

cardboard were passed behind the fan blades and stapled to the colored disc. It was necessary to have the disc centered upon the fan. The disc in Fig. 2, was mounted on the hand rotor wheel.

The stroboscope was operated in both a light and a dark room. When it was in a light room, the rotating color disc was observed through the holes in the rotating shutter disc; and when it was in a dark room, the color disc was illuminated at regular intervals by a projected light coming through the openings of the shutter disc. If a motion picture machine is available, it can be used to replace the rotor wheel, shutter disc, and light source when used in the dark room. The results are similar in all cases. The effect was that each design on the colored disc appeared to be rotating forward, backward, or standing still independent of each other. Different designs and effects were produced by changing the speed of either the colored disc or the shutter disc.

A SPECTROSCOPE

The spectroscope is found in only a few of the better equipped high school laboratories. This is because of the expense of the instrument rather than the impracticability of its use. The project illustrated in Fig. 4, Plate XIX,

EXPLANATION OF PLATE XXXI

Fig. 1. Working drawing for the spectroscope.

Fig. 2. Detail of the adjustable slit.

PLATE X[illegible]

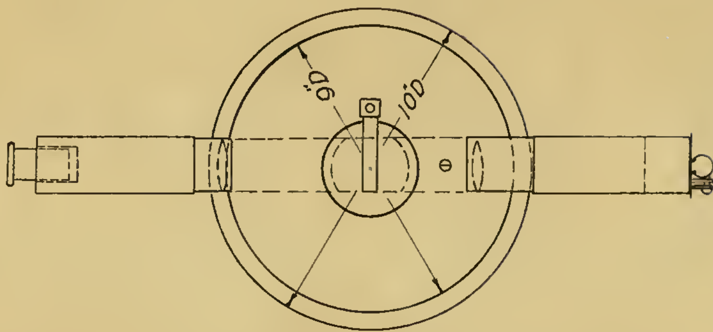
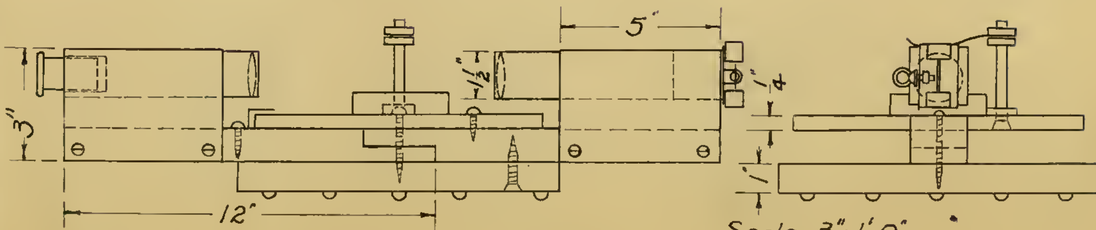


Fig. 2



Scale: 3" = 1'-0"

Fig. 1

gave good results and it was built for as many pennies as a commercial one would cost in dollars.

List of Materials

1 plywood board	1/4" x 8" diameter
1 hardwood board	3/4" x 10" diameter
2 hardwood boards	3/4" x 1 1/2" x 12"
2 hardwood boards	3/4" x 1 1/2" x 5"
2 pieces tinplate 28 gauge	5" X 7"
2 pieces tinplate 28 gauge	5" X 8 1/2"
1 piece tinplate 24 gauge	1 5/8" x 1 5/8"
2 pieces tinplate 28 gauge	1/2" x 1 3/4"
1 piece tinplate 24 gauge	1 1/2" x 2"
1 plywood board	1/4" x 3/4" diameter
2 semicircular spring clips	1/2" x 3/4" diameter
1 brass rivet	3/16"x 1/2"
1 No. 8 R.H. 1 1/2" wood screw	
10 No. 6 R.H. 3/4" wood screws	
1 stove bolt threaded to the head with two nuts	1/4" x 3"
1 can lid	1/2" x 3" diameter
1 clock spring	3/8" x 3"
1 small bolt with nut	3/16"x 3/4"
12" No. 12 wire	
flexible cardboard	5" x 6"
1 circular protractor (360 degrees)	8"
2 double convex lens	6" focal length
1 Ramsden eye piece	
8 rubber-headed tacks	

The spectroscope was built on a ten-inch circular base that was studded on the bottom with rubber headed tacks. Two arms, twelve inches long, were joined together at the ends with a half-lap joint. This joint was cut so that one arm was fastened to the base, the other arm rotated about a screw through the center of the joint and into the

center of the base. The telescope was mounted on the movable arm and the collimator was mounted on the stationary arm. The eight-inch plywood disc had a circular protractor glued to its face. A hole was drilled through the exact center of this disc. Then a screw was placed through this hole, through the two arms, and into the center of the base. The three-inch plywood disc was riveted to the can lid with a rivet through their centers so that the disc could turn about the rivet freely. Small lugs were soldered to the edge of this can lid so it was centered on the protractor. It was fastened down with small wood screws. This made a small turntable for mounting prisms, gratings, and mirrors. The three-inch stove bolt that had been threaded to the head was mounted through the protractor table from the bottom side with its head countersunk in the plywood. A washer and nut on the top of the table held it in place. This bolt was mounted at one edge of the can lid and at an angle of ninety degrees from the fixed arm. A three-inch piece of clock spring was soldered to a nut that fitted the stove bolt. Thus nut made an adjustable spring for holding the optical specimens when it was screwed down on the stove bolt. A piece of tinplate, one and one-half inch by two inches, was pointed at one end and fastened to the movable arm in such a manner that the pointed end formed an indicator by which

the angle of the movable arm could be read.

The telescope was made by forming a tube, one and one-half inches in diameter. A piece of number twelve wire was soldered around the inside of one end of the tube. The lens was mounted against the wire and held by a cardboard cylinder pressed against the lens as shown in Fig. 8, Plate I. The eye-piece was mounted in a smaller tube that was soldered in place by means of a tin washer cut to proper size. The cross-hair was mounted half-way between the lenses of the eye-piece, rather than the conventional way. This gave good results and was easier to do.

The collimator was made with a tube the same size as that used for the telescope. A double convex lens was mounted at the focal length of the lens from one end of the tube. The adjustable slit was built on the end of the tube. This consisted of a piece of square tin centered and soldered to the end of the tube, then a vertical one-half inch opening was cut in this end plate. Two, one-half by one and three quarters inch pieces of tin were bent with hooks that were one eighth inch at each end. They formed two sliders that made the adjustable slit. One slider was centered and soldered while the other was made adjustable as shown in Fig. 2, Plate XXXI. The five-inch blocks of wood were fastened on top of the arms and flush at the ends. The telescope and collimator were mounted on top of

these and held in place by a sheet of tin over all. This arrangement allowed the optical units to be adjusted at varying distances from the center of the spectroscope.

When this instrument was used with a neon lamp and a grating it gave excellent results. It also gave good results when used with a glass prism. It made a worthwhile addition to the laboratory.

A DOUBLE CONVEX LENS MODEL

This problem was the result of a search for a transparent material that could be worked successfully with common tools. This project is an example of what can be done with this material and suggests many other uses. The commercial name of the material is lucite. It is sold by several jobbers in the form of rods, sheets, cylinders, and blocks. It is also made in colors. Its index of refraction is 1.52, which makes it suitable for making lenses and other optical equipment. The project shown in Fig. 4, Plate XIX, was built to show the principles of the double convex lens.

List of Materials

1 hardwood board	4"	x 3"	x 13"
1 piece lucite	1/2"	x 3"	x 3"
2 copper tubes	1/4"	x 1 1/2"	
2 No. 8, R.H. 3/4" wood screws			
6 ' No. 18 iron wire			
4 glazier points			
Enamel: red, yellow, green, black			

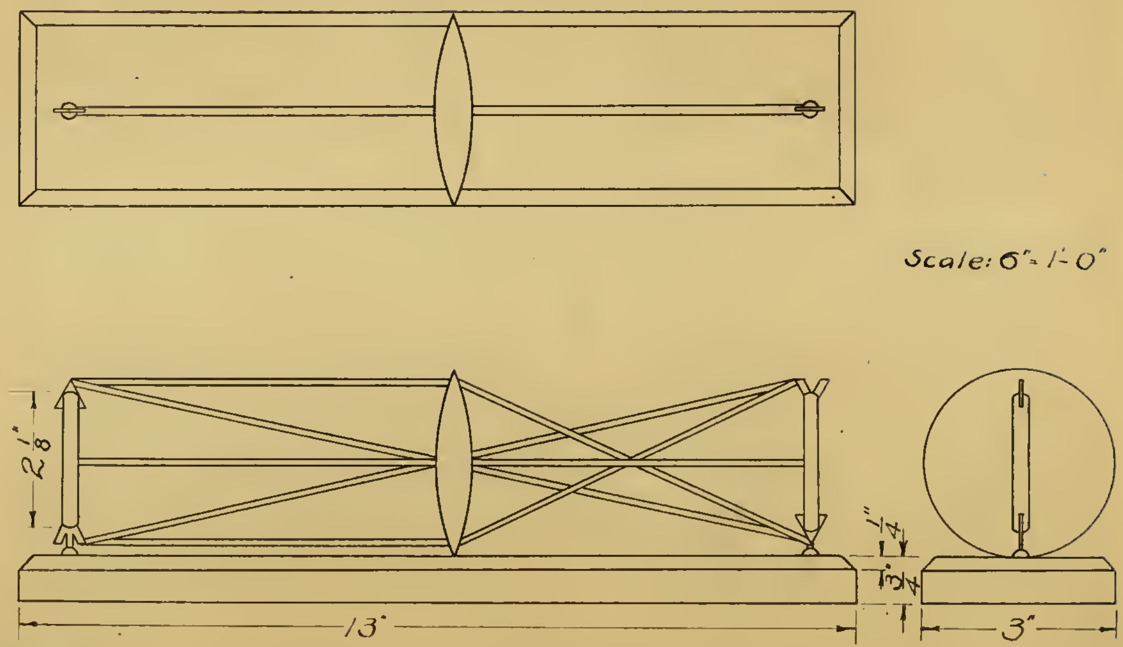
The lens was turned to shape on the face plate of a wood lathe. The work was done at the lowest speed because lucite softens and gums when it becomes hot. A pattern was made for the desired curvature from a piece of celluloid. One face of the lens was turned out and polished with rouge. Then the lucite was turned over and the other side was cut out and polished. Then the holes for the wires were marked out and drilled. Soap is used as the lubricant for drilling holes in lucite.

The object and image were made by making arrows from glazier points as shown in Fig. 1, Plate I. These were soldered to the ends of the two pieces of copper tubes. A short piece of wire with a small loop in it was soldered to the bottom of the object and image for mounting them to the base. The principal axis and the parallel rays were shaped and soldered into place. The lines through the center of the lens were cut in sections because they could not cross in the center of the lens. After the

EXPLANATION OF PLATE XXXII

Working drawing for the double convex lens model.

PLATE XXXI.



project was assembled, it was enameled as follows: the object and image red, the parallel rays green, the rays through the center of the lens yellow, and the base black.

Lucite is inexpensive and fascinating to work with. The possibilities for its use and application open up a new field for research.

THE EXHIBIT CASE

Students should be given recognition for good work in as many ways as possible. The development of a science exhibit case is one way of doing this effectively (2). The case should be built in some prominent place where electricity is available. The case is used to exhibit work done by students of the department. It may be drawings, models, projects, special demonstrations, or any other constructive work.

The exhibit case used in the Yates Center High School had a push-button mounted outside the case. This made it possible for students to operate the electrical apparatus exhibited at any time. Students not in the science classes became interested in the work of the science department. The students became interested in working out new ideas. The following list is a few of the demonstrations exhibited in that case during the last year:

1. "Jacobs ladder"
   A V-shaped spark gap in which the spark started at the bottom, climbed to the top, broke, then started over again.

2. "Perpetual motion"
   A radiometer placed in a strong light.

3. "The grapevine swing"
   A swing made of an electrical conductor supported in a strong magnetic field. When the push-button was pressed the swing started.

4. Exhibit of etched glass.

5. Exhibits of chemical gardens.

6. Student-made Geissler tubes.

7. "Jumping ring".

8. Meters showing the electrical consumption of an electric toaster.

CONCLUSION

This work should be of value to schools, science teachers, and club sponsors for one or more of the following reasons.

1. To make possible a clearer, more concrete presentation of the fundamental laws of physics through special simplified apparatus and models.
2. To maintain interest and appreciation through special demonstrations and projects.

3. To give the student the opportunity to apply his knowledge through special projects that he can formulate.
4. To increase the interest of the parents and other patrons of the school.
5. To make the budget expenditures more efficient.

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